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EFFECTS OF A NBC NUTRIENT SOLUTION ON PHYSIOLOGICAL AND PSYCHOLOGICAL STATUS DURING SUSTAINED ACTIVITY IN THE HEAT

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Soldiers involved in nuclear, biological, and chemical (NBC) warfare may be encapsulated in MOPP4 ensemble for up to 24 hours. In that configuration the soldier is in a fasting state unless he can move to a decontaminated area to eat. The purpose of this study was to determine if a nutrient solution containing 2.34% carbohydrate and 24.1 mEq sodium per liter (NBC Nutrient solution) would be more effective than a control solution of colored and flavored water in maintaining the physiological and psychological status of a person under thermal conditions that simulate MOPP4 encapsulation. Twelve healthy young males were exercised at 400 watts in a climatic chamber to produce a sweating rate of 0.5 liters/h (98^{o}F, 20% rh, 2 mph wind speed). The data for one subject were not included in some of the physiological and psychological analyses because of an upper respiratory infection. Each subject was tested on both solutions and the assignment of solutions was counterbalanced. The subjects were to be tested for a maximum of 24 hours on the NBC Nutrient solution and 24 hours on the control solution; actual endurance times were 17.1+3.6 (Mean+SD) and 16.0+2.9

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hours, respectively. Fluid intake was encouraged and the subjects maintained hydration fairly well.

The increase in blood glucose levels and delayed appearance of urinary ketones for subjects drinking the NBC Nutrient solution were noteworthy physiological differences between the two solutions. Water was as effective as the NBC Nutrient solution in maintaining cardiovascular, thermoregulatory, and hydration status. No significant differences were noted in the cognitive, motor performance, and vigilance tests. The NBC Nutrient solution significantly lowered self-reported symptom intensity and improved mood after 6 hours. The NBC Nutrient solution was significantly more acceptable and preferred over the flavored water; this might alter the results of tests in which subjects are allowed to consume the fluids ad libitum or of tests in field situations in which soldiers don't drink enough. Test data from hours 12-24 were inconclusive because of the reduced numbers of subjects but suggested that the NBC Nutrient solution might affect physiological and psychological performance in studies which are more stressful or of longer duration.

The results of this study indicated that water and the NBC Nutrient solution were equally effective in maintaining hydration and physiological status under hot dry conditions. The NBC Nutrient solution was more palatable, lowered symptom intensity, and improved mood; cognitive performance was not improved.

HUMAN RESEARCH and DISCLAIMER STATEMENTS

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

TECHNICAL REPORT No. T25-87

EFFECTS OF A NBC NUTRIENT SOLUTION ON PHYSIOLOGICAL AND PSYCHOLOGICAL STATUS DURING SUSTAINED ACTIVITY IN THE HEAT

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FOREWORD

The purpose of this study was to test a nutrient solution (NBC Nutrient solution) recommended by a National Research Council advisory committee for soldiers working in the heat wearing Nuclear, Biological, Chemical (NBC) protective clothing (MOPP4). The NRC committee recommended the NBC Nutrient solution for use by soldiers encapsulated in the MOPP4 ensemble for 24 hours, engaged in moderate activity, sweating at about 0.5 liters/hour, and working where the Wet Bulb Globe Temperature did not exceed 21°C (70°F). To focus on the comparison of the NBC Nutrient solution to water without the complications of remaining in MOPP4 configuration for 24 hours, the soldiers were studied in no MOPP configuration (shorts and running shoes) under thermal conditions that simulated the heat stress of wearing the MOPP4 ensemble.

This technical report is a compilation of eight separate sections of physiological and psychological tests written by the individual authors. Each section contains its own methods, results, discussion, conclusions, references, tables, and figures. The literature review, general methods, integrated summary, general conclusions, and recommendations contain an overall view of the study.

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ABSTRACT

Soldiers involved in nuclear, biological, and chemical (NBC) warfare may be encapsulated in MOPP4 ensemble for up to 24 hours. In that configuration the soldier is in a fasting state unless he can move to a decontaminated area to eat. The purpose of this study was to determine if a nutrient solution containing 2.34% carbohydrate and 24.1 mEq sodium per liter (NBC Nutrient solution) would be more effective than a control solution of colored and flavored water in maintaining the physiological and psychological status of a person under thermal conditions that simulate MOPP4 encapsulation. Twelve healthy young males were exercised at 400 watts in a climatic chamber to produce a sweating rate of 0.5 liters/hour (98°F, 20% rh, 2 mph wind speed). The data for one subject were not included in some of the physiological and psychological analyses because of an upper respiratory infection. Each subject was tested on both solutions and the assignment of solutions was counterbalanced. The subjects were to be tested for a maximum of 24 hours on the NBC Nutrient solution and 24 hours on the control solution; actual endurance times were 17.1 ± 3.6 (Mean±SD) and 16.0 ± 2.9 hours, respectively. Fluid intake was encouraged and the subjects maintained hydration fairly well.

The increase in blood glucose levels and delayed appearance of urinary ketones for subjects drinking the NBC Nutrient solution were noteworthy physiological differences between the two solutions. Water was as effective as the NBC Nutrient solution in maintaining cardiovascular, thermoregulatory, and hydration status. No significant differences were noted in the cognitive, motor performance, and vigilance tests. The NBC Nutrient solution

significantly lowered self-reported symptom intensity and improved mood after 6 hours. The NBC Nutrient solution was significantly more acceptable and preferred over the flavored water; this might alter the results of tests in which subjects are allowed to consume the fluids ad libitum or of tests in field situations in which soldiers don't drink enough. Test data from hours 12-24 were inconclusive because of the reduced numbers of subjects but suggested that the NBC Nutrient solution might affect physiological and psychological performance in studies which are more stressful or of longer duration.

The results of this study indicated that water and the NBC Nutrient solution were equally effective in maintaining hydration and physiological status under hot dry conditions. The NBC Nutrient solution was more palatable, lowered symptom intensity, and improved mood; cognitive performance was not improved.

INTRODUCTION

In 1982 a National Research Council (NRC) Committee (1) recommended a nutrient solution that would be suitable to sustain military personnel in the Nuclear, Biological, and Chemical (NBC) ensemble for 24 hours (NBC Nutrient solution). The solution was not envisioned to meet all nutrient needs but would allow the individual to function for 24 hours while drawing on body nutrient stores. The committee felt that the casualty rate from heat stress for individuals engaged in heavy work while wearing protective clothing would not be reduced by any nutrient solution because the rate of heat storage was a function of the metabolic rate, environmental conditions, and clothing characteristics. Nonetheless, the NRC Committee did recommend a fluid replacement plan to avoid heat injury for soldiers working for sustained periods (24 hours) of moderate activity (300 watt workload, WBGT 21°C) where sufficient thermal exchange could occur (Appendix 1). The Committee concluded that water would meet the soldier's needs for the first 6 hours. After 6 hours they recommended the NBC Nutrient solution that would contain a minimum of 500 kcal and a maximum of 250 mEq sodium (Na^+) in 6 liters of solution to be consumed over the next 18 hours (Appendix 2). The NBC Nutrient solution would optimize physical performance by: replacing body water losses, providing glucose to prevent hypoglycemia and ketosis, replacing approximately 50% of the Na^+ loss, and providing calories to lessen muscle glycogen depletion.

Current doctrine and the design of the M-17A2 mask restricts semi-solid and solid food intake by soldiers in the mission-oriented protective posture 4 (MOPP4) ensemble*. This will result in a fasting state unless they can enter collective protection units to eat (2) or they are provided a nutrient containing solution which will allow them to use the current mask drinking system. It had been predicted that soldiers would be in the MOPP4 ensemble no more than 24 hours when the NBC Nutrient Solution was formulated (1). However, due to the unpredictability of providing food supplies in wartime, there is a possibility of longer periods of food deprivation.

The capacity to perform physical work decreases during starvation (3-6), and the deterioration is dependent on the duration of the starvation period and on the level of physical activity (3,5). Starvation affects four components of performance: endurance, strength, speed, and coordination (5). Subjects doing sustained work suffer from increased heart rate (5) and considerable nausea and side pain (3) while strength is not affected (3,5,7) in the first 5 days of starvation. A reduction in speed, coordination, and psychomotor performance during the starvation period appears to be dependent on reduced blood glucose (3,8) and can be reversed with the administration of sugar (3). Kety (14) reported that a significant decrease in the blood glucose level is consistently associated with manifestations of impaired mental function.

The metabolic acidosis of starvation can result in an altered total body water and thereby reduce physical performance (7). The loss of ketones produces a concomitant loss of sodium and an accompanying water loss (7,9-13)

*MOPP4 is the military designation for the NBC ensemble consisting of M-17A2 mask, protective overgarments, gloves, and rubber boots.

which may lead to dehydration. Urinary ketosis indicates a depletion of carbohydrate (CHO) reserves and a shift to lipids as the preferred substrate (4,15). It requires from 8 to 40 days for the brain to shift to using ketones as a primary fuel (16). Ketosis does not affect psychometric testing in the first 24 hours of starvation; however there is a deterioration at the end of the 24 hours (3). Gamble (17) has shown that 50 g of carbohydrate/day is needed to prevent ketosis and the obligatory loss of sodium and water. Several investigators (14,18,19) have reported that the minimum amount of carbohydrate needed by the glucose dependent tissues ranges from 50-200 g/day for the central nervous system (CNS), eye lens, and erythrocytes.

Twenty four hours of sustained work is difficult, and when the person is deprived of food, the ability to work is decreased. Prolonged severe exercise can elicit hyperthermia (20,21), depletion of muscle glycogen (22,23), and hypoglycemia (24,25). Attempts to reduce these effects by liquid nutritional support during exercise have produced mixed results. The optimal nutrient solution should (a) be absorbed rapidly from the digestive system allowing for maximal fluid delivery to the body and maintenance of an adequate hydration level, (b) provide carbohydrate to the blood thereby sparing muscle and liver glycogen stores and preventing hypoglycemia; and (c) provide minerals to replace those lost during heavy sweating (26,27).

Hypohydration is a major factor that can affect performance and recovery from physical activity (28-30). Hypohydration causing greater than a 2% reduction in body weight will decrease plasma volume, increase osmolality, decrease stroke volume and cardiac output, increase heart rate, increase core temperature, and reduce sweat rate and cutaneous blood flow (29,31-37).

Significant loss of water with accompanying losses of sodium, potassium, magnesium, and calcium can predispose an individual to developing heat cramps, exhaustion, and stroke. Hypohydration can adversely affect discipline and morale and lead to moroseness, aggressiveness, and obvious signs of fatigue (29).

Optimal performance of a fully acclimatized person, performing intermittent hard work in the heat, is achieved by continually replacing the water lost in sweat (31). Small frequent sips of water (38) are recommended to prevent dehydration and attendant hyperthermia. However, subjects drinking water ad libitum tend to delay drinking and then consume all their fluid at one time (29). Observers have reported that subjects will voluntarily dehydrate when fluid requirements are high and thus will lose greater than 2.0% body weight (13,29). Adequate hydration helps maintain body temperature during exercise (21,30,31) in the heat. If sufficient water is ingested ad libitum, core temperature is maintained at a lower level than for a subject who voluntarily reduces fluid consumption (31).

The second major factor that can affect performance is carbohydrate depletion (28). Use of carbohydrates to prolong work time has been investigated (23,25,30,39,40-44) but the results have not always been unequivocal (45-47). Restriction of carbohydrate intake can lead to lower levels of blood glucose and muscle glycogen, two of the major fuels for muscular contraction. Hypoglycemia resulting from depletion of liver glycogen has been shown to be the most important factor inducing fatigue during continuous and intermittent exercise (48-51) in rats. However, exhaustion has not been clearly associated with hypoglycemia in humans (47).

Glucose concentrations as low as 5% can retard gastric emptying

(26,52-58) and reduce the absorption of the ingested fluid. The volume of nutrient solutions emptied from the stomach is delayed as the osmolar concentration of the gastric contents increases. This delayed emptying of hyperosmotic gastric content can cause nausea and discomfort. Coyle (54) reported that plain water emptied 39% faster than a 4.6% glucose solution. Neufer et al. (58) observed that water emptied 22% faster than a 5% maltidextrin solution, and exercise at 50-70% $\dot{V}O_2max$ increased gastric emptying. The total carbohydrate delivered from a 5% carbohydrate solution is inadequate to meet the carbohydrate requirement of heavy exercise (24). However, continued ingestion of a carbohydrate solution can stabilize blood glucose levels and thus the work rate (31,41-43,59-63) when compared to water.

The third major factor that may affect performance is electrolyte balance. Costill (64) described electrolyte losses in the sweat, and observed sodium losses of 40-60 mEq/L sweat. While excessive sweating results in large water losses but not equally large electrolyte losses (65), 12 liters of sweat could result in losses of 480-720 mEq of sodium.

Researchers do not agree on the need for electrolyte replacement during exercise in the heat. Francis (66) recommended supplementation of sodium and potassium. Frizzell et al. (67) reported on two cases of hyponatremia resulting from excessive consumption of dilute fluids (about 20 liters containing 196 mEq Na^+) during excessive sweating in ultramarathon running, and concluded that under these conditions some replacement of sodium is necessary. Pitts et al. (31) reported that replacement of salt hour by hour during heavy sweating has no demonstrable advantage for fully acclimatized

men who receive adequate amounts of salt in their daily diet. There was a tendency for 0.2% aqueous saline solution to maintain the rate of sweating better than plain water but performance was not improved (31). Americans usually ingest 10-15 g NaCl/day (68) when only 250 mg of sodium (0.625 g NaCl) is needed to meet the physiologic needs of people who do not experience excessive fluid loss. Most research on salt replacement studied the problem for 2-6 hour periods (31,65) with losses up to 1.5 liters of sweat/hour, followed by a meal soon afterward. However, moderate sustained activity for 24 hours in a hot environment could cause losses of up to 12 liters of sweat and 480-720 mEq (1104-1656 mg) of Na^+ per day (40-60 mEq Na^+/L sweat). Food deprivation could preclude salt replacement and available food may not be eaten because of ignorance or anorexia in the heat. Sustained exercise, excessive fluid loss due to heavy sweating, and lack of regular meals suggest that some replacement of sodium may be important.

A nutrient solution designed for 24 hours of sustained exercise should contain <5% carbohydrate so as not to delay gastric emptying; provide >50-100 g carbohydrate/day to prevent hypoglycemia and metabolic acidosis; and contain enough sodium to replace a portion of the 480-720 mEq Na^+ loss. The NBC Nutrient Solution meets all the criteria for a successful nutrient solution for sustained exercise, but studies are needed to determine if the NBC Nutrient Solution will improve sustained performance under hot environmental conditions. Testing of the NBC Nutrient solution on soldiers in MOPP4 ensemble would be preferred. However testing subjects in MOPP4 configuration introduces extraneous problems (i.e. facial itch due to beards in the mask, urine and fecal excretion in an ensemble that is not designed to

address the problem, computer testing with bulky gloves, etc.) which might interfere with a sustained test of physiological and psychological variables. Another consideration in testing the NBC Nutrient solution should be the method of hydration. Allowing *ad libitum* intake of the solution would give important data on differences due to the acceptability of the NBC Nutrient solution but would make it very difficult to determine the effects of the solution when hypohydration is not a major intervening variable.

OBJECTIVES

The objectives of this study were to determine the effects of the NBC Nutrient solution on the following variables:

1. nutritional status
2. thermoregulation during exercise in the heat
3. endurance capacity
4. vigilance and alertness
5. leg strength and lifting capacity
6. solution acceptance, hunger, and thirst as a function of time
7. cognitive state and motor performance skills
8. subjective reactions

The NBC Nutrient solution was tested without MOPP encapsulation but under environmental conditions that would simulate working in MOPP4 configuration for sustained periods (24 hours) at moderate activity (300 watt workload, WBGT 21°C) (Appendix 1). Fluid intake was encouraged to prevent dehydration from complicating the comparison of the NBC Nutrient solution to water on physiological and psychological variables.

REFERENCES

1. Conclusions and recommendations arising from a workshop, held June 3-4, 1982, to determine nutritional requirements of military personnel in protective clothing, Committee on Nutritional Requirements in Protective Clothing, Food and Nutrition Board, Commission on Life Sciences, National Research Council.

2. Headquarters Dept of the Army. NBC Protection, Field Manual No. 3-4. Washington, DC: U.S. Army Adjutant General Publications Center, 1985.

3. Henschel A, Taylor HL, Keys A. Performance capacity in acute starvation with hard work. J Appl Physiol 1954;6:624-633.

4. Taylor HL, Henschel A, Mickelsen O, Keys A. Some effects of acute starvation with hard work on body weight, body fluids and metabolism. J Appl Physiol 1954;6:613-623.

5. Consolazio CF, Nelson RA, Johnson HL, Matoush LO, Krzywicki HJ, Issac GJ. Metabolic aspects of acute starvation in normal humans: Performance and cardiovascular evaluation function. (Laboratory Report No. 298) Denver, CO: US Army Med Res Nut Lab, 1966.

6. Lategola MT. The effect of 5-day, complete starvation on cardiopulmonary functions of aerobic work capacity and orthostatic tolerance. Fed Proc 1965;24:590.

7. Taylor HL, Brozek J, Henschel A, Mickelsen O, Keys A. The effect of successive fasts on the ability of men to withstand fasting during hard work. Am J Physiol 1945;143:148-155.

8. Guetzkow H, Taylor HL, Brozek J, Keys A. Relationship of speed of motor reaction to blood sugar level during acute starvation in man, abstracted. Fed Proc 1945;4:28.

9. Bloom WL, Mitchell W Jr. Salt excretion of fasting patients. Arch Intern Med 1960;106:71-76.

10. North KAK, Lascelles D, Coates P. The mechanisms by which sodium excretion is increased during a fast but reduced on subsequent carbohydrate feeding. Clin Sci Mol Med 1974;46:423-432.

11. Sigler MH. The mechanism of the natriuresis of fasting. J Clin Invest 1975;55:377-387.

12. Consolazio CF, Matoush LO, Johnson HL, Nelson RA, Krzywicki HJ. Metabolic aspects of acute starvation in normal humans (10 days). (Laboratory Report No. 299) Denver, CO: US Army Med Res Nut Lab, 1966.

13. Kerndt PR, Naughton JL, Driscoll CE, Loxterkamp DA. Fasting: The history, pathophysiology and complications. West J Med 1982;137:379-399.

14. Kety SS. The general metabolism of the brain in vivo. In: Richter D, ed. Metabolism of the nervous system. New York: Pergamon Press, 1957: 221-237.

15. Drury DR, Wick AN, MacKay EM. The action of exercise on ketosis. Am J Physiol 1941;134:761-768.

16. Cahill GE, Aoki TT. Partial and total starvation. In: Assessment of energy metabolism in health and disease. Columbus, OH: Ross Laboratories, 1980:129-134.

17. Gamble JL. Physiological information gained from studies on the life raft ration. Harvey Lect. 1946-47;42:247-273.

18. Consolazio CF, Johnson HL. Dietary carbohydrate and work capacity. Am J Clin Nutr 1972;25:85-90.

19. Cahill GF. Starvation in man. New Eng J Med 1970;282:668-675.

20. Maron MB, Wagner JA, Horvath SM. Thermoregulatory responses during competitive marathon running. J Appl Physiol 1977;42:909-914.

21. Costill DL, Kammer WF, Fisher A. Fluid ingestion during distance running. Arch Environ Health 1970;21:520-525.

22. Karlsson J, Saltin B. Diet, muscle glycogen, and endurance performance. J Appl Physiol 1971;31:203-206.

23. Ahlborg B, Bergstrom J, Ekelund LG, Hultman E. Muscle glycogen and muscle electrolytes during prolonged physical exercise. Acta Physiol Scand 1967;70:129-142.

24. Pirnay F, Lacroix M, Mosora F, Luyckx A, Lefebvre P. Effect of glucose ingestion on energy substrate utilization during prolonged muscular exercise. Eur J Applied Physiol 1977;36:247-254.

25. Costill DL, Bennett A, Branam G, Eddy D. Glucose ingestion at rest and during prolonged exercise. J Appl Physiol 1973;34:764-769.

26. Foster C, Costill DL, Fink WJ. Gastric-emptying characteristics of glucose and glucose polymer solutions. Res Q Exer Sport 1980;51:299-305.

27. Seiple RS, Vivian VM, Fox EL, Bartels RL. Gastric-emptying characteristics of two glucose polymers-electrolyte solutions. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983:85-87.

28. Williams MH. Nutritional aspects of human physical and athletic performance. Springfield, IL: Charles C. Thomas Publisher, 1976:44-75 and 169-207.

29. Strydom NB, Wyndham CH, van Graan CH, Holdsworth LD, Morrison JF. The influence of water restriction on the performance of men during a prolonged march. So Afr Medical J 1966;31:539-544.

30. Macaraeg PVJ Jr. Influence of carbohydrate electrolyte ingestion on running endurance. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983:91-96.

31. Pitts GC, Johnson RE, Consolazio FC. Work in the heat as affected by intake of water, salt and glucose. Am J Physiol 1944;142:253-259.

32. Ladell WSS. The effects of water and salt intake upon the performance of men working in hot and humid environments. J Physiol 1955;127:11-46.

33. Adolph EF, Brown AH, Goddard DR, Gosselin RE, Kelly JJ, Molnar GW, Rahn H, Rothstein A, Towbin EJ, Wills JH, Wold AV. In: Physiology of man in the desert. New York: Interscience Publishers, 1947.

34. Wyndham CH. Heat stroke and hyperthermia in marathon runners. In: Milvy P, ed. The marathon: Physiological, medical, epidemiological, and psychological studies. New York: New York Academy of Sciences, 1977: 128-138.

35. Keys A, Brozek J, Henschel A, Mickelsen O, Taylor HL. Human starvation. U. of Minn Press, 1951.

36. Consolazio CF, Johnson RE, Pecora LJ. Physiological measurements of metabolic function in man. New York: Blakiston Division, McGraw-Hill Book Co., 1963.

37. Saltin B. Aerobic and anaerobic work capacity after dehydration. J Appl Physiol 1964;19:1114-1118.

38. Kenney RA. The effect of the drinking pattern on water economy in hot, humid environments. Brit J Industr Med 1954;11:38-39.

39. Coyle EF. Effects of glucose polymers feedings on fatigability and the metabolic response to prolonged strenuous exercise. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983:43-49.

40. Ivy JL, Miller W, Dover V, Goodyear LG, Sherman WM, Farrell S. Enhanced performance with carbohydrate supplements during endurance exercise. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983:54-60.

41. Bonen A, Malcolm SA, Kilgour RD, MacIntyre KP, Belcastro AN. Glucose ingestion before and during intense exercise. J Appl Physiol 1981;50:766-771.

42. Brooke JD, Davis GJ, Green LF. The effects of normal and glucose syrup work diets on the performance of racing cyclists. J Sports Med 1975;15:257-265.

43. Ivy JL, Costill DL, Fink WJ, Lower RW. Influence of caffeine and carbohydrate feedings on endurance performance. Med Sci Sports 1979;11:6-11.

44. Macaraeg PVJ, Abad-Santos C, Zarraga W. Rehydration with glucose polymer/fructose electrolyte solution during prolonged heavy exercise. In: Proceedings of the 22nd World Congress on Sports Medicine, 1982:53.

45. Ivy JL. Influence of carbohydrate feedings on endurance exercise of high intensity. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983: 49-53.

46. Felig P, Cherif A, Minagawa A, Wahren J. Hypoglycemia during prolonged exercise in normal men. N Engl J Med 1982; 306:895-900.

47. Fruth JM, Gisolfi CV. Effects of carbohydrate consumption on endurance performance: Fructose versus glucose. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983:68-75.

48. Fell RD, McLane JA, Winder WW, Holloszy JO. Preferential resynthesis of muscle glycogen in fasting rats after exhausting exercise. Am J Physiol 1980;238:R328-R332.

49. Gaesser GA, Brooks GA. Glycogen repletion following continuous and intermittent exercise to exhaustion. J Appl Physiol 1980;49:722-728.

50. Reitman J, Baldwin KM, Holloszy JO. Intramuscular triglyceride utilization by red, white, and intermediate skeletal muscle and heart during exhaustive exercise. Proc Soc Exp Biol Med 1973;142:628-631.

51. Terjung RL, Baldwin KM, Winder WW, Holloszy JO. Glycogen repletion in different types of muscle and in liver after exhausting exercise. Am J Physiol 1974;226:1387-1391.

52. Costill DL, Saltin B. Factors limiting gastric emptying during rest and exercise. J Appl Physiol 1974;37:679-683.

53. Hunt JN. The site of receptors slowing gastric emptying in response to starch in test meals. J Physiol 1960;154:270-276.

54. Coyle EF, Costill DL, Fink WJ, Hoopes DG. Gastric emptying rates for selected athletic drinks. Res Q 1978;49:119-124.

55. Daum F, Cohen MJ, McNamara H, Finberg L. Intestinal osmolality and carbohydrate absorption in rats treated with polymerized glucose. Pediatr Res 1978;12:24-26.

56. Elias E, Gibson GJ, Greenwood LF, Hunt JN, Tripp JH. The slowing of gastric emptying by monosaccharides and disaccharides in test meals. J Physiol 1968;194:317-326.

57. Hunt JN, Pathak JD. The osmotic effects o. some simple molecules and ions on gastric emptying. J Physiol 1960;154:254-269.

58. Neufer PD, Costill DL, Fink WJ, Kirwan JP, Fielding RA, Flynn MG. Effects of exercise and carbohydrate composition on gastric emptying. Med Sci Sports Exerc 1986;18:658-662.

59. Ahlborg G, Felig P. Substrate utilization during prolonged exercise preceded by ingestion of glucose. Am J Physiol 1977;233:E188-E194.

60. Bueding E, Goldfarb W. Blood Changes following glucose, lactate and pyruvate injections in man. J Biol Chem 1943;147:33-40.

61. Hermansen L, Pruett EDR, Osnes JB, Giere FA. Blood glucose and plasma insulin in response to maximal exercise and glucose infusion. J Appl Physiol 1970;29:13-16.

62. Wahren J, Felig P, Ahlborg G, Jorfeldt L. Glucose metabolism during leg exercise in man. J. Clin Invest 1971;50:2715-2725.

63. Norris WA, Kanonchoff AD, Prall V, Rupp J, Fox EL, Bartels RL, Hecker AL. Metabolic response to an experimental hydration solution in long-term exercise. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983: 87-91.

64. Costill DL. Sweating: Its composition and effects on body fluids. In: Milvy P, ed. The marathon: Physiological, medical epidemiological, and psychological studies. New York: New York Academy of Sciences, 1977: 160-174.

65. Kozlowski S, Saltin B. Effect of sweat loss on body fluids. J Appl Physiol 1964;19:1119-1124.

66. Francis KT. Effect of water and electrolyte replacement during exercise in the heat on biochemical indices of stress and performance. Aviat Space Environ Med 1979;50:115-119.

67. Frizzell RT, Lang GH, Lowance DC, Lathan SR. Hyponatremia and ultramarathon running. JAMA 1986;255:772-774.

68. Committee on Dietary Allowances, Food and Nutrition Board, Commission on Life Sciences, National Research Council. Recommended Dietary Allowances. 9th ed. Washington, DC: National Academy Press, 1980.

GENERAL METHODS

Twelve male subjects between the ages of 18 and 35 years volunteered for this test after a full disclosure of the objectives, methods, and risks of the study. The data from one subject (#6) were not included in some of the physiological and psychological analyses because of an upper respiratory infection that affected temperature, heart rate, etc. The subjects were tested on two different fluids. The NBC Nutrient solution contained 562 kcal, 140 g carbohydrate (2.34%), and 145 mEq Na^{+} (0.056%) in 6 liters of solution with an osmolality of 160-180 mOsm/kg. The control solution was water containing the same amount of coloring and flavoring as was added to the NBC Nutrient solution (Appendix 2). Aspartame should have been included in the control solution to approximate the sweetness of the NBC Nutrient solution but was inadvertantly excluded. Cool (15°C) spring water was used to prepare both the control and NBC Nutrient solution. Both solutions were stored at room temperature until they were taken into the climatic chamber. Six subjects were tested at any one time, the assignment of the solutions was counterbalanced to minimize the effects of order of administration.

The training and 24-hour Heat Stress portions of the study were conducted in a large environmental chamber equipped with two 4-man treadmills. The following conditions were carefully controlled during the 24-hour Heat Stress tests: fluid consumption was encouraged to maintain euhydration (0.5 liter/hour sweat rate), 24 hours of sustained activity (45 min work/45 min rest), a mean metabolic rate during exercise of about 400 watt (3.5 mph, level treadmill), and a hot/dry environment (37°C, 20% rh, wind speed=2 mph).

GENERAL METHODS

The study was composed of 4 phases: I) 10-days of training and heat acclimation, II) 24-hour Heat Stress test with ingestion of one fluid, III) 6 days of recuperation, and IV) another 24-hour Heat Stress test with ingestion of the second fluid (Appendix 3). The complete cycle of tests (4 phases) lasted approximately 3 weeks.

During phase I the subjects were heat- and exercise-acclimated and trained in all tasks that they would perform during the 24-hour tests. The 10-day training period was selected to eliminate the confounding effects of progressive acclimation and learning. Ingestion of the control solution and the NBC Nutrient Solution was encouraged during the acclimation sessions to familiarize the subjects with the flavors of the two solutions and to collect baseline acceptance data. Subjects were instructed as to the importance of maintaining hydration. Pre-test baseline data were collected. Each subject's post-breakfast body weight was determined daily during the training week to establish a baseline. Body composition measurements of lean body mass and percent body fat were determined by hydrostatic weighing. Pre-testing for muscle strength was conducted from 1000-1400 hours on the day prior to the 24-hour Heat Stress test. Maximal aerobic power was determined by a treadmill running test. During the training phase, subjects were heat acclimated by walking on a level treadmill in a hot (37°C, 50% rh, wind speed=2 mph) environment.

During a 24-hour Heat Stress Test day the tests were conducted in a hot-dry (37°C, 20% rh, wind speed=2 mph) environment. The subjects collected their urine as soon as they awoke on the test day (PRE). The volunteers reported to the climatic chambers facility at 0600 hours to eat a light

breakfast consisting of orange juice, bananas, cold cereal, milk, bagels, and donuts. The subjects proceeded to the locker room facility to be instrumented with a rectal thermistor (10-cm insertion) and a three point skin harness. ECG electrodes were attached and connected to a battery powered transmitter carried in a belt pouch for ECG telemetry. Subjects were weighed nude (post urination) and again after dressing and instrumentation. The assigned clothing was shorts, T-shirts, socks, and tennis shoes (MOPP0). The subjects were fitted with an in-dwelling venous catheter (butterfly-type) equipped with a heparin lock (forearm vein). A baseline (PRE) venous blood (14 ml) was drawn after the subject had stood quietly for 20 minutes in a comfortable (20°C) environment. As soon as the subjects entered the climatic chamber they were weighed with all their equipment and the Food Acceptance and Subjective Self-Report Questionnaire was administered.

The 24 hours of the Heat Stress test (repetitions of 45 min exercise, 45 min rest/test) was divided into six hour blocks and the sequence of events was similar in each six hour block (Appendix 4). Subjects had the right to terminate testing voluntarily without prejudice, and most of the subjects withdrew prior to completing 24-hours of testing ($\bar{X}_{NBC}=17.1 \pm 3.6$ h, $\bar{X}_{control}=16.0 \pm 2.9$ h, General Assessment section). None of the subjects reached the pre-set safety criteria (180 bpm heart rate or 39.5°C rectal temperature) for medical termination from the study (Appendix 5). During the Heat Stress Tests, the subjects ingested the control solution or the NBC Nutrient Solution *ad libitum* except for a 15-minute period prior to blood drawing and during timed tests. This 15-minute period was used to control for gastrointestinal absorption biasing the collected blood samples. During

the rest periods the subjects were weighed and rehydrated as necessary with the control solution/NBC Nutrient Solution to maintain baseline body weight (±2%). Body temperature and heart rate were continuously monitored. Venous blood samples (about 5 ml) were withdrawn 30 minutes into every even numbered exercise bout, and all urine was collected during the rest periods. The Food Acceptance and Subjective Self-Report Questionnaire was distributed to each subject on every even numbered rest period. The Cognitive, Motor Performance, and Self-Reported Symptoms and Mood States tests were administered every 6 hours.

When the soldiers voluntarily ended participation or at the 24th hour, whichever came first, the venous blood, urine, and weights were sampled again for the post-test measurements. A final Self-Reported Symptoms and Mood States test and the Food Acceptance and Subjective Self-Report post-test questionnaire were administered before the subject could leave the chamber. Post-testing for muscle strength was conducted for those subjects that had completed 24 hours of testing.

PHYSIOLOGICAL ASSESSMENT

PHYSIOLOGICAL ASSESSMENT

GENERAL ASSESSMENT

METHODS

Subjects were weighed on a K-120 Sauter balance prior to the start of the first exercise bout, after every exercise bout, and when participation was terminated in the 24-hour heat stress test.

Each subject was given a 500 cc container of the appropriate solution. When the container was emptied, another container was furnished. The subjects were encouraged to drink at least 500 cc of fluid per hour and encouraged to drink whenever their body weight fell below the starting weight. Fluid intake was recorded as the subject was given a new container of fluid and when unconsumed fluids were returned.

The time that had elapsed when a subject terminated the heat stress test was recorded and used to calculate endurance time.

Statistical Analysis

Descriptive data are presented for all 12 subjects who participated in this study but data for subject #6 were not included in the statistical analyses in this section. A paired T-test was used to compare the data for NBC Nutrient solution to that of the control solution to test for significant differences. Data are presented as Mean$\pm$SD.

RESULTS

The physical characteristics of 11 subjects who completed the study are presented in Table 1. Because the twelfth subject (#6) fell ill with an

upper respiratory infection after completing the NBC trial but before starting the control trial, his data were not included in some of the physiological and psychological analyses that may have been affected by his illness. The mean percent body fat (15.9±6.5%) was average for young men but the values ranged from very lean to slightly obese. The relative $\dot{V}O_2max$ (54.2±7.8 ml/kg/min) indicated above average aerobic fitness for the group with a range from somewhat low (42.1 ml/kg/min) to very high aerobic fitness (63.5 ml/kg/min).

Results indicated that efforts to maintain euhydration by forcing fluids were fairly successful. The sweating rate and fluid intake data (Table 2) indicated that the subjects were receiving enough fluid to replace sweat (NBC 738.9±249.3 ml/hour, Control 663.1±195.9 ml/hour). While the difference in fluid intake was not statistically significant, the fluid intake for the control trial was 10% less than for the NBC trial. However, the relatively high urinary output placed the subjects in a slightly negative fluid balance as indicated by their weight loss. Pre-test differences in body weight between the two fluid trials were not significant (Figure 1) which indicated that the subjects were able to maintain their baseline weights. There were no significant differences between the pre- minus post-test body weights for each 24-hour test. There was a slightly greater but statistically insignificant overall weight loss pre- to post-test during the control trial (1.60±1.19 kg, 1.98%) compared to the NBC Nutrient solution trial (1.05±0.78 kg, 1.35%).

The total experimental time spent in exercising and testing (endurance time) for each subject and solution is presented in Table 3. The means for

the two trials were not significantly different ($\bar{X}_{NBC}$=17.1$\pm$3.6 h, 29.8 miles; $\bar{X}_{control}$=16.0$\pm$2.9 h, 28.0 miles). The effects of the order of administration (first or second 24-h test) on endurance times for the control solution data were not significantly different. However, the order of administration caused a significant difference ($p<0.05$) in endurance times for the NBC Nutrient solution trial in as much as the subjects who received the NBC Nutrient solution in the first 24-hour test lasted longer, and this trial contained the only subjects to complete 24 hours of the study. The range of endurance times for the NBC Nutrient solution trial was 13.25 to 24 hours whereas the range for the control solution was 9 to 20.5 hours. The reasons that were given for discontinuing the experiment were varied, but the major reasons were foot problems and blisters (Table 4, Appendix 5).

The muscle strength and muscular endurance data could not be used to compare the two solutions because only subjects drinking the NBC Nutrient solution completed the 24-hour tests (Appendix 6). The subjects drinking the control solution had a maximum endurance time of 20.5 hours.

The diet histories for the two days prior to the 24-hour tests (Tables 5 & 6) showed that the caloric intakes were not significantly different (Table 7). The subjects ate a light breakfast on the morning of the study (Tables 8 & 9) and the pre-study breakfast meals were not significantly different (Table 10) for the two fluid conditions.

GENERAL ASSESSMENT

DISCUSSION

The small amount of weight loss (<2% body weight) in both fluid trials demonstrated that hydration was maintained. Despite frequent attempts to replace all weight loss with fluid, efforts were unsuccessful, demonstrating the difficulty in maintaining hydration status during exercise in the heat. Previous food deprivation studies have shown that weight loss of normal individuals usually averages about 1.2 kg/day (1-3). The weight loss for both fluid conditions was similar to previous studies and not significantly different from each other. The subjects lost more weight when drinking the control solution (1.60$\pm$1.19 kg) compared to the NBC Nutrient solution (1.05$\pm$0.78 kg) even though the fluid balance for both trials was similar (difference of 5.9 cc/h). Since the subjects in the control trial were in a food deprived state, the difference in weight loss might be attributed to a negative energy balance rather than to dehydration. It is possible that maintenance of body weight would have overhydrated the subjects in both trials since they were in a caloric deficient state. The mean weight loss (1.99%) for the control trial was slightly, but not significantly greater than for the NBC Nutrient solution trial but less than the 2-3% (4-11) that is considered indicative of dehydration.

There were no significant differences between the two solutions in terms of endurance time. While the subjects were motivated to participate in the study, it was not possible to motivate them to complete both 24-hour tests to the same extent that might be experienced during combat. Most subjects had to leave the study due to reasons that were extraneous to the intent of the

test such as foot problems and chafing. It is not anticipated that soldiers would need to walk 42 miles (3.5 mph x 12 h of walking) to remove themselves from the presence of NBC agents. Mixing exercise types may have more accurately reflected a real life scenario; however, treadmill exercise allowed a controlled workload comparison between the control and NBC Nutrient solutions. In addition, it was used to elicit the desired sweating rates with a minimum of local fatigue as occurs during many other types of exercise.

Another variable that was not anticipated was the individual recovery time from blisters between the administration of the two solutions. The randomized crossover design was adopted to account for the possibility of an insufficient recovery time and for the possibility of decreased motivation to participate in the second 24-hour test but recovery time for blisters was not considered. The data showed that the order of presentation of the NBC Nutrient solution did affect the endurance time. A longer recovery period might have decreased the effects of the order of administration for the NBC Nutrient solution.

The ability of an individual to sustain an optimal level of performance in a state of food deprivation is contingent on many variables, many of which are interdependent (12). Some of the factors that are most relevant to this study as stated by Pellett (12) are: the level and frequency of activity, environmental temperature and humidity, previous energy stores, age, health, physiological status, and any physiological or psychological stresses during the food deprivation period that may affect hormonal status. These variables may determine the efficacy of any nutrient solution to sustain an individual

for a long period of time in a state of semi-starvation. Three subjects (including subject #6) completed an entire 24-hour session in the heat and it is interesting that all were ingesting the NBC Nutrient solution. However the mean endurance time (excluding subject #6) for the NBC Nutrient solution (17 h) was not significantly greater than for the control solution (16 h). Other complaints such as sore feet, chafing, foot blisters, and heat rash, apparently not directly related to exhaustion, made it difficult to determine the effects of the NBC Nutrient solution on endurance time.

CONCLUSIONS

1. The subjects maintained hydration fairly well (<2% weight loss). While there was no significant difference between trials, during the NBC Nutrient solution trial the subjects lost 1.05 kg (1.35%) body weight and 1.60 kg (1.98%) was lost during the control trial.
2. The endurance time for the NBC Nutrient solution (17.1 ± 3.6 hours) was longer than for the control solution (16.0 ± 2.9 hours) but the difference was not significant.

REFERENCES

1. Lategola MT. The effect of 5-day, complete starvation on cardiopulmonary functions of aerobic work capacity and orthostatic tolerance. Fed Proc 1965;24:590.

2. Consolazio CF, Matoush LO, Johnson HL, Nelson RA, Krzywicki HJ. Metabolic aspects of acute starvation in normal humans (10 days). (Laboratory Report No. 299) Denver, CO: US Army Med Res Nut Lab, 1966.

3. Johnson RE. Final report to US Army Medical Research and Development Command. Dept of Army, DA Contract #49-194-MD-222, Washington, DC, 1965.

4. Strydom NB, Wyndham CH, van Graan CH, Holdsworth LD, Morrison JF. The influence of water restriction on the performance of men during a prolonged march. So Afr Medical J 1966;31:539-544.

5. Pitts GC, Johnson RE, Consolazio FC. Work in the heat as affected by intake of water, salt and glucose. Am J Physiol 1944;142:253-259.

6. Ladell WSS. The effects of water and salt intake upon the performance of men working in hot and humid environments. J Physiol 1955;127:11-46.

7. Adolph EF, Brown AH, Goddard DR, Gosselin RE, Kelly JJ, Molnar GW, Rahn H, Rothstein A, Towbin EJ, Wills JH, Wold AV. In: Physiology of man in the desert. New York: Interscience Publishers, 1947.

8. Wyndham CH. Heat stroke and hyperthermia in marathon runners. In: Milvy P, ed. The marathon: Physiological, medical, epidemiological, and psychological studies. New York: New York Academy of Sciences, 1977: 128-138.

9. Keys A, Brozek J, Henschel A, Mickelsen O, Taylor HL. Human starvation. U. of Minn Press, 1951.

10. Consolazio CF, Johnson RE, Pecora LJ. Physiological measurements of metabolic function in man. New York: Blakiston Division, McGraw-Hill Book Co., 1963.

11. Saltin B. Aerobic and anaerobic work capacity after dehydration. J Appl Physiol 1964;19:1114-1118.

12. Pellett PL. The physiology of hunger and malnutrition. In: Forbes MH, Merrill LJ, eds. Global hunger: A look at the problem and potential solutions. Chicago: Univ of Evansville Press, 1986:37-104.

Table 1. Physical characteristics of subjects that completed the NBC Nutrient Solution and control solution trials (n=11)[1].

Variable	Mean±SD	Range
Age, years	23.5± 4.6	19.00- 32.00
Height, cm	176.2± 5.2	165.00-183.00
Weight, kg	78.7±12.7	59.65- 97.05
Body fat, %	15.9± 6.5	6.60- 27.50
$\dot{V}O_2$max, l/min	4.2± 0.5	2.96- 4.98
$\dot{V}O_2$max, ml/kg/min	54.2± 7.8	42.10- 63.50

[1]Excluding subject #6.

Table 2. Fluid balance for subjects consuming the NBC Nutrient solution and a control solution.[1,2]

FLUIDS	CONTROL SOLUTION	NBC NUTRIENT SOLUTION	p
OUTPUT			
Sweating Rate (ml/h)	518.0 ± 205.0	547.0 ± 194.0	NS
Urine Output (ml/h)	228.6 ± 139.5	281.3 ± 186.1	NS
INTAKE			
Fluid Intake (ml/h)	663.1 ± 195.9	738.9 ± 249.3	NS
BALANCE (ml/h)	-83.5	-89.4	

[1]Excluding subject #6.

[2]Mean$\pm$SD

Table 3. Endurance time for the NBC Nutrient solution and the control solution during 24-hour heat stress trials.

Number of Hours Completed (hours: min)		
SUBJECT	CONTROL SOLUTION	NBC NUTRIENT SOLUTION
1	13:30	16:40
2	17:50	24:00
3	16:32	13:17
4	16:20	15:17
5	15:40	16:10
6	9:45	24.00
7	16:15	14:45
8	9:00	15:05
9	16:15	14:45
10	16:32	16:10
12	20:35	24:00
13	17:48	17:37
Mean[1,2]	16:00 (16.0±2.9 h)	17:06 (17.1±3.6 h)
p	NS	

[1]Excluding Subject #6.

[2]Mean±SD in parentheses.

Table 4. Reasons for terminating participation in the 24-hour heat stress trials.

SUBJECT	CONTROL SOLUTION	NBC NUTRIENT SOLUTION
1	Heat Rash	Chafing from probe
2	Too tired, exhausted	Finished 24-h test
3	Chafing between legs, leg cramps	Chafing between legs
4	Too tired, dehydrated, will not drink	Foot blisters, heat rash
5	Leg cramps, heat rash	Feet gave out, exhausted, cold, weaving on treadmill
6	URI, sore throat, feels terrible	Finished 24-h test
7	Sore knees	Sore knees & ankles, chafing
8	Feet hurt	Feet hurt
9	Blisters	Sore knees, blisters
10	Nauseated, light-headed, headache	Chafing rectal probe
12	Fatigue	Finished 24-h test
13	Blisters	Blisters

Table 5. Diet history for the two days (Mean) prior to the 24-hour heat stress test for the control trial.

Subject	Kcal	CHO(g)	Pro(g)	Fat(g)	Na^+(mg)
1	1154.0	150.0	49.0	40.3	3586.5
2	3492.0	427.0	116.6	146.5	2482.0
3	1718.5	150.9	87.7	83.8	2044.5
4	2085.0	298.1	74.6	69.6	4473.5
5	1617.0	265.1	556.5	40.7	2519.0
6	2127.5	162.8	108.0	116.3	2792.0
7	2872.0	229.3	161.0	146.0	6875.0
8	1563.0	170.6	75.4	65.3	1675.5
9	3905.5	544.6	146.3	127.2	4120.5
10	1329.0	190.7	38.7	48.3	1401.5
12	2078.5	244.5	106.5	74.1	3423.0
13	2549.0	242.7	129.4	120.1	3928.5

Table 6. Diet History for the two days (Mean) prior to the 24-hour heat stress test for the NBC Nutrient Solution trial.

Subject	Kcal	CHO(g)	Pro(g)	Fat(g)	Na^{+}(mg)
1	1786.0	234.7	70.6	65.7	3131.0
2	2805.0	360.7	81.2	116.0	3550.0
3	2446.5	211.0	128.8	120.0	2398.5
4	1923.0	288.2	121.0	59.05	2221.0
5	3010.5	453.0	108.8	81.6	6452.0
6	1586.5	133.6	75.1	83.3	3230.5
7	3496.5	364.0	164.8	154.8	3912.0
8	2207.5	337.1	67.0	70.5	1996.0
9	2528.5	273.5	109.5	111.0	2125.0
10	2539.5	199.3	138.8	132.2	2436.0
12	1969.5	232.7	74.1	82.7	2608.0
13	3036.0	340.6	148.6	124.0	5110.0

Table 7. Dietary composition of food intake for 2 days prior to the 24-hour heat stress tests for the control and NBC Nutrient solution trials.[1]

FLUID CONDITION		Kcal	CHO (g/day)	Protein (g/day)	Fat (g/day)	Na^+ (mg/day)
Control	Mean	2214.9	264.9	140.2	87.4	3320.9
	SD	894.8	121.8	143.3	40.6	1562.6
NBC	Mean	2522.6	299.5	110.3	101.6	3267.2
	SD	533.2	78.7	33.6	31.2	1412.4
p		NS	NS	NS	NS	NS

[1]Excluding subject #6.

Table 8. Diet history for breakfast meal on the day of the 24-hour heat stress test for the control trial (Mean).

Subject	Kcal	CHO(g)	Pro(g)	Fat(g)	Na^+(mg)
1	826.0	118.8	53.4	24.4	1025.0
2	895.0	184.0	31.9	8.1	688.0
3	756.0	109.8	21.6	27.1	792.0
4	1100.0	173.4	33.2	30.3	1246.0
5	1475.0	220.2	53.0	44.6	1784.0
6	536.0	69.5	22.4	20.6	637.0
7	840.0	132.1	35.9	18.4	1127.0
8	889.0	157.4	25.1	23.0	1169.0
9	780.0	141.8	22.3	15.9	573.0
10	335.0	49.7	4.2	13.6	329.0
12	710.0	99.3	16.3	29.7	836.0
13	1248.0	161.6	45.5	48.0	1612.0

Table 9. Diet History for the breakfast meal on the morning of the 24-hour heat stress test for the NBC Nutrient Solution trial (Mean).

Subject	Kcal	CHO(g)	Pro(g)	Fat(g)	Na^{+}(mg)
1	354.0	53.8	4.4	13.6	332.0
2	869.0	142.5	30.2	20.3	1027.0
3	1265.0	203.4	34.1	37.9	1226.0
4	1374.0	297.6	60.5	8.9	1652.0
5	1532.0	261.4	40.9	38.3	1569.0
6	882.0	127.7	33.5	26.7	1142.0
7	1204.0	193.4	39.5	32.5	1237.0
8	650.0	96.8	19.2	21.1	943.0
9	804.0	139.9	25.0	16.5	819.0
10	554.0	119.8	18.6	2.9	854.0
12	596.0	96.2	14.9	16.6	699.0
13	725.0	115.7	20.5	21.2	941.0

Table 10. Dietary composition of the breakfast meal on the study days for the control and NBC Nutrient solution trials[1].

FLUID CONDITION		Kcal	CHO(g)	Pro(g)	Fat(g)	Na^+(mg)
Control	Mean	895.8	140.7	31.1	25.7	1016.5
	SD	298.5	46.4	15.4	12.3	435.0
NBC	Mean	902.5	156.4	28.0	20.9	1027.2
	SD	382.5	74.6	15.4	11.3	380.3
p		NS	NS	NS	NS	NS

[1]Excluding subject #6.

FIGURE LEGEND

Figure 1. Body weight (kg) after each 45 minute exercise bout in the heat for the NBC Nutrient solution and control solution (colored and flavored water). Each subject participated in both trials (n=11).

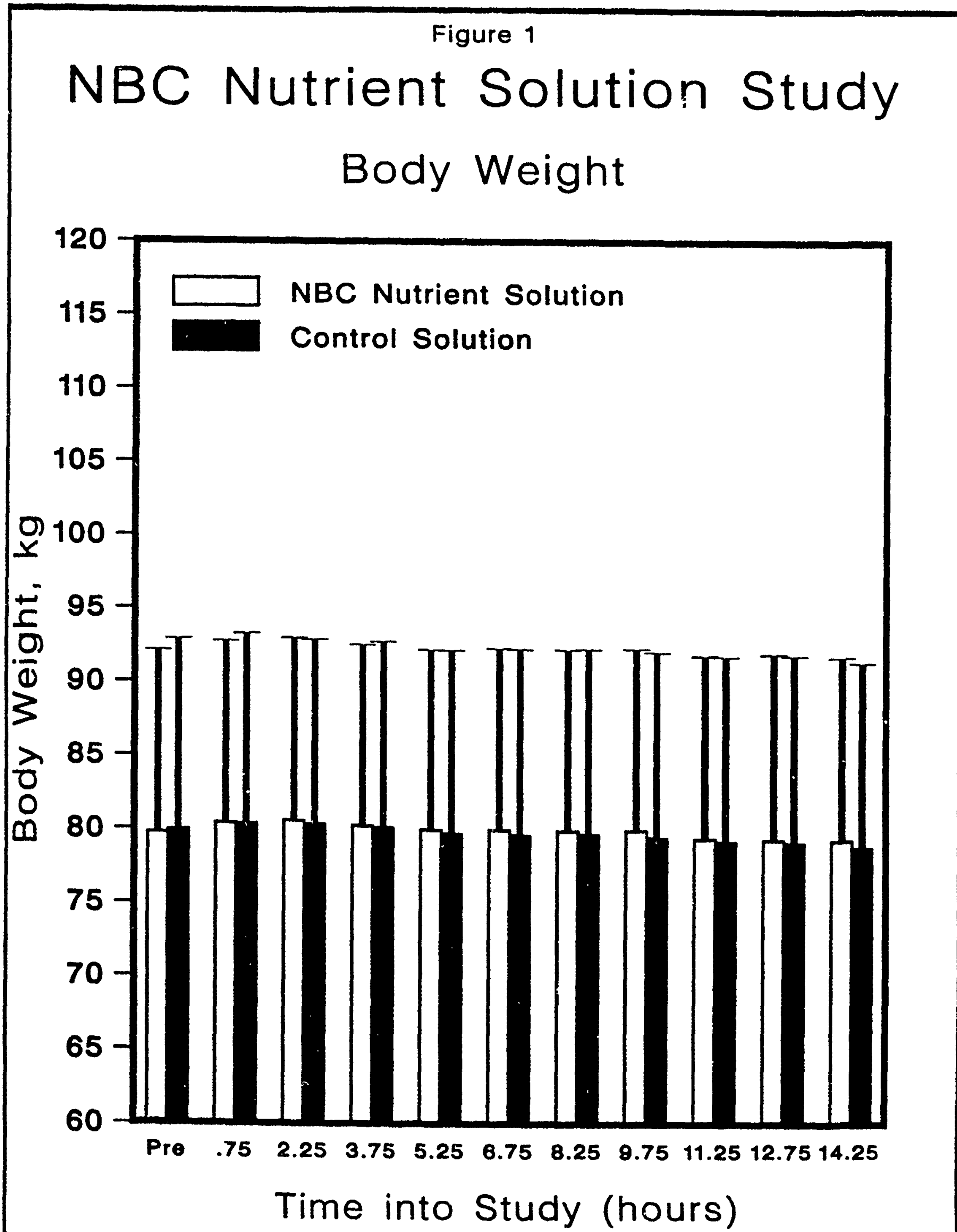


Figure 1
NBC Nutrient Solution Study
Body Weight
NBC Nutrient Solution
Control Solution
Body Weight, kg
120
115
110
105
100
95
90
85
80
75
70
65
60
Pre
.75
2.25
3.75
5.25
6.75
8.25
9.75
11.25
12.75
14.25
Time into Study (hours)

CARDIOVASCULAR AND THERMAL REGULATION

METHODS

Heat Acclimation and Maximal Aerobic Power Determination

Heat acclimation consisted of daily treadmill walking at 1.56 $m \cdot sec^{-1}$ (3.5 mph) and 0% grade for two 50-minute exercise bouts separated by a 10-min rest, in a hot environment (T_a=37°C, rh=50%, wind speed=2 mph). Heart rate (HR) and rectal temperature (T_{re}) were continuously monitored during these sessions. All testing was conducted while subjects wore gym shorts, T-shirts, socks and comfortable athletic shoes. Drinking of fluids was encouraged throughout the acclimation process. For the first five subjects, who were partially heat acclimated from previous heat exposure, the acclimation process was complete after six days (days 4 and 5 were separated by two weekend days). Two additional heat acclimation days were included between the two 24-hour tests to insure maintenance of acclimation status. For the last six subjects, who were not previously exposed to a hot environment, the acclimation schedule was five consecutive days, a weekend (two days) off, followed by three more heat acclimation days. For these subjects, the acclimation process was complete by the eighth day. Two additional acclimation days were also included for this group between the two 24-h tests. Due to scheduling conflicts for testing facilities, this second group of six subjects was required to acclimate in a smaller environmental chamber on days 1, 3, 5 and 6. The subjects walked on a level treadmill, as described, for one 50 min exercise bout, and for the other exercise bout they performed cycle exercise (60 rpm) at 90W to approximate the exercise intensity of the treadmill exercise ($\dot{V}O_2 \sim 1.1$ ℓ O_2/min). The environmental

conditions were similar. Because in this smaller chamber humidity could not be maintained below 50%, all of the acclimation was conducted at this relative humidity level. Criteria for the attainment of heat acclimation were the achievement of equivalent final T_{re} and HR on two consecutive heat acclimation days. Only those days where testing occurred in the large environmental chamber (where only treadmill exercise was employed) were used in these determinations.

A maximal aerobic power test was conducted in the afternoon during the acclimation week. The maximal treadmill test was progressive in intensity and continuous in nature. The initial treadmill grade was zero, and was increased by 2.5% increments for each 1.5-minute exercise bout. Each subject's running velocity (2.68 or 3.13 $m \cdot sec^{-1}$) was determined from his heart rate response to a 5-minute warm-up walk (1.56 $m \cdot sec^{-1}$ at 10% grade). If the elicited heart rate response equalled or was greater than 145 bpm, the 2.68 $m \cdot sec^{-1}$ velocity was selected for the maximal test. Established criteria were employed for determination of peak $\dot{V}O_2$ for the 2.68 $m \cdot sec^{-1}$ (6 mph) and 3.13 $m \cdot sec^{-1}$ (7 mph) tests (1,2).

<u>24-Hour Heat Stress Tests</u>

During the 24-hour tests, electrocardiograms were obtained with chest electrodes (CM 5 placement) and continuously radiotelemetered to an oscilloscope-cardiotachometer unit (Hewlett-Packard). Rectal temperature was recorded from a flexible thermistor probe (Yellow Springs Instrument, Inc. [YSI]) inserted ~ 10 cm beyond the anal sphincter. Skin temperature was monitored with a three-point thermocouple skin harness (chest, calf, forearm) and mean weighted skin temperature ($\bar{T}_{sk}$) was calculated (3). During the

45-min exercise sessions, T_{re} and $\bar{T}_{sk}$ were recorded and plotted for each subject at 2-min intervals. During the 45-min periods when subjects were not exercising, T_{re} was monitored with a portable YSI telethermometer. Testing was terminated for any subject whose T_{re} reached 39.5°C, or whose HR reached or exceeded 180 $b \cdot min^{-1}$ for five consecutive minutes during exercise. In addition, exercise was terminated at the request of the test subject, or at the discretion of the medical monitor. Body weights were determined using a K-120 Sauter precision electronic balance (accuracy$\pm$10g). Total body sweating rates ($\dot{M}_{sw}$) were calculated from body weight changes adjusted for fluid intake and urine output, determined after each exercise bout. During the first and every odd numbered exercise bout, oxygen uptake (STPD) was determined by open-circuit spirometry. Timed collections of mixed expired air (Douglas bags) were analyzed for O_2 and CO_2 concentrations using an O_2 fuel cell (Applied Electrochemistry S-3A) and an infrared CO_2 analyzer (Beckman LB-2), respectively. Expired gas volume was measured in a Tissot spirometer. Respiratory exchange ratio (RER) and aerobic metabolic rates were calculated.

Statistical Analysis

A two-way repeated measures analysis of variance (ANOVA) was employed to determine if treatment (control solution or NBC Nutrient solution) or time significantly influenced any of the measured variables. If significant main effects or interactions were found, Tukey's honestly significant difference (HSD) procedure was used to determine where differences occurred. For our purposes, we have divided the 24-h tests into 16 sessions consisting of 45

min rest, 45 min exercise, and have labeled them according to number of hours of testing.

For the ANOVA, only the first nine of the 16 sessions (control n=10, NBC n=11) were used because of decreasing sample size after this time. For measurements of T_{re}, $\bar{T}_{sk}$, and HR, the values presented represent subject responses during the last 2 minutes of each 45-min exercise bout. Metabolic rates were determined at ~30 min of every other exercise bout. Sweating rates were calculated from the end of one exercise bout to the end of the next, and include the 45-min rest between bouts (except for the first calculation at 0.75 hours which included only 10 min of rest and 45 min of exercise). In all cases, statistical significance was accepted at $p<0.05$ level. Data reported are means$\pm$SE.

RESULTS

Figure 1 presents the T_{re} responses for the control and NBC Nutrient solution experiments. No differences were found between the two treatments during the first 12.75 h (9 exercise bouts). Mean T_{re} responses generally increased ($p<0.01$) over time for both drinks, and after 12.75 h were 37.75$\pm$0.07°C for the control and 37.98$\pm$0.07°C for the NBC Nutrient solution experiments. The predetermined T_{re} end-point criteria of 39.5°C was not approached during any exercise bout for any of the subjects in either trial.

As seen in Figure 2, the $\bar{T}_{sk}$ values were not different between treatments and generally increased ($p<0.01$) over time during both trials. The $\bar{T}_{sk}$ values after 12.75 h were 35.13$\pm$0.21°C for the control and 35.35$\pm$0.17°C for the NBC Nutrient solution experiments.

//

Figure 3 presents the HR responses for the control and NBC Nutrient solution trials. No differences were found between the two treatments during the first 12.75 h of testing. The HR responses generally increased ($p<0.05$) over time, but never approached the 180 bpm end-point criteria during any bout. After the ninth exercise bout HR were 109±5 bpm for the control and 108±4 bpm for the NBC Nutrient solution experiments.

Metabolic rate illustrated in Figure 4 was not different between treatments and remained constant over time during the control experiment, but was elevated by 12.75 h compared to 3.75 h during the NBC Nutrient solution trial. The metabolic rate during the ninth exercise bout (12.75 h) was 416±27 watt for the control and 435±27 watt for the NBC Nutrient solution experiments.

Figure 5 presents the $\hat{M}_{sw}$ responses for the control and NBC Nutrient solution experiments. No differences were found between the two treatments during the first 12.75 h of testing, and there was no time effect. The overall mean $\hat{M}_{sw}$ value for the first 12.75 hours was 518±22 g/h for the control and 547±20 g/h for the NBC Nutrient solution experiments.

Because of small and decreasing sample size as the test progressed beyond 13 hours or nine exercise bouts, statistical analyses were not employed for data collected after that time. However, observations were made of data for the two subjects who completed approximately 18 and 21 hours during the control trial and the entire 24 hours during the NBC Nutrient solution trial. While no conclusions can be drawn regarding data from such a small sample, these observations offer no evidence of responses or trends other than those reported for the group as a whole. Rectal temperatures for

these two subjects were even more similar between the control and NBC Nutrient solution trials than were the mean responses for the group, and did not appear to continue increasing over time beyond the ninth exercise bout. Skin temperatures were similar to the group means. For $\dot{M}_{sw}$, HR, and metabolic rate, one subject's responses were again, almost identical between trials, while the other subject's responses followed the trends established by the group.

DISCUSSION

This study was successful in meeting the requirements (as stated by the National Research Council Committee, Appendix 1) needed to test the NBC Nutrient solution with regard to exercise intensity, duration, and sweating rates. The subjects exercised for a prolonged time at an intensity of approximately 400 W (5.7 kcal/min). The combination of exercise and environment resulted in sweating rates of approximately 500 grams per hour. A subject who lasted an average of ~16 hours in this test secreted ~8 liters of sweat. During these experiments, both solutions were replaced at a rate approximately equal to sweat loss to maintain euhydration, as dehydration is known to reduce exercise performance.

Our data clearly demonstrate that under these conditions, the NBC Nutrient solution provided no thermoregulatory or cardiovascular advantage compared to the control solution. This is evidenced in the data observed for rectal and skin temperatures, sweating rate, heart rate and metabolic rate. If anything, there is a tendency for most responses to be slightly elevated during the NBC Nutrient solution trial compared to the control trial.

There are two hypotheses that can possibly explain this trend. The slightly elevated (non-significant) T_{re} observed during the NBC Nutrient solution trial may reflect the higher plasma osmolalities reported in this paper in the section on Hydrational Status. Previous research has shown an association between increased body temperature and increased plasma osmolalities (4,5) The increased thermal strain may then have caused the higher HR.

The second possible explanation for these slight, non-significant differences relates the higher T_{re} and HR to the somewhat elevated metabolic rates. We might speculate that during the NBC Nutrient solution trial the subjects were somewhat more active, and therefore expended slightly more energy. However, during the metabolic data collection periods, great effort was made to control for any extraneous activity that would influence the measurements. In this paper in the section on Self-Reported Symptoms and Mood States, the investigators report that after six hours of testing the subjects may have been feeling better when they were drinking the NBC Nutrient solution. Speculation aside, however, our results show that these small differences between the NBC Nutrient and the control solutions were not significant, nor did they approach significance.

REFERENCES

1. Mitchell JH, Sproule BJ, Chapman CB. The physiological meaning of the maximal oxygen intake test. J Clin Invest 1958;37:538-547.

2. Taylor HL, Buskirk ER, Henschel A. Maximal oxygen intake as an objective measure of cardio-respiratory performance. J Appl Physiol 1955;8:73-80.

3. Burton, AC. Human calorimetry. II. The average temperature of the tissues of the body. J Nutr 1935;9:261-280.

4. Sawka, MN, Young AJ, Francesconi RP, Muza SR, Pandolf KB. Thermoregulatory and blood responses during exercise at graded hypohydration levels. J Appl Physiol 1985;59:1394-1401.

5. Harrison MH, Edwards RJ, Fennessy PA. Intravascular volume and tonicity as factors in the regulation of body temperature. J Appl Physiol 1978;44:69-75.

FIGURE LEGENDS

Figure 1. Rectal temperature (X±SE) during treadmill exercise in the heat (37°C, 20% rh). Each data point represents the last value collected in each of the first nine 45-min exercise bouts. (45 min of rest was interspersed between each exercise bout). For the control solution trial (circles), n=11, while for the NBC Nutrient solution trial (squares) n=10 because one subject did not complete nine bouts.

Figure 2. Mean weighted skin temperature for conditions and time as described in Figure 1.

Figure 3. Heart Rate for conditions and time as described in Figure 1.

Figure 4. Metabolic Rate for conditions as described in Figure 1. Metabolic rates were calculated from $\dot{V}O_2$ measurements made ~30 min into the first and every alternate exercise bout.

Figure 5. Total body sweating rate for conditions and time as described in Figure 1.

Figure 1

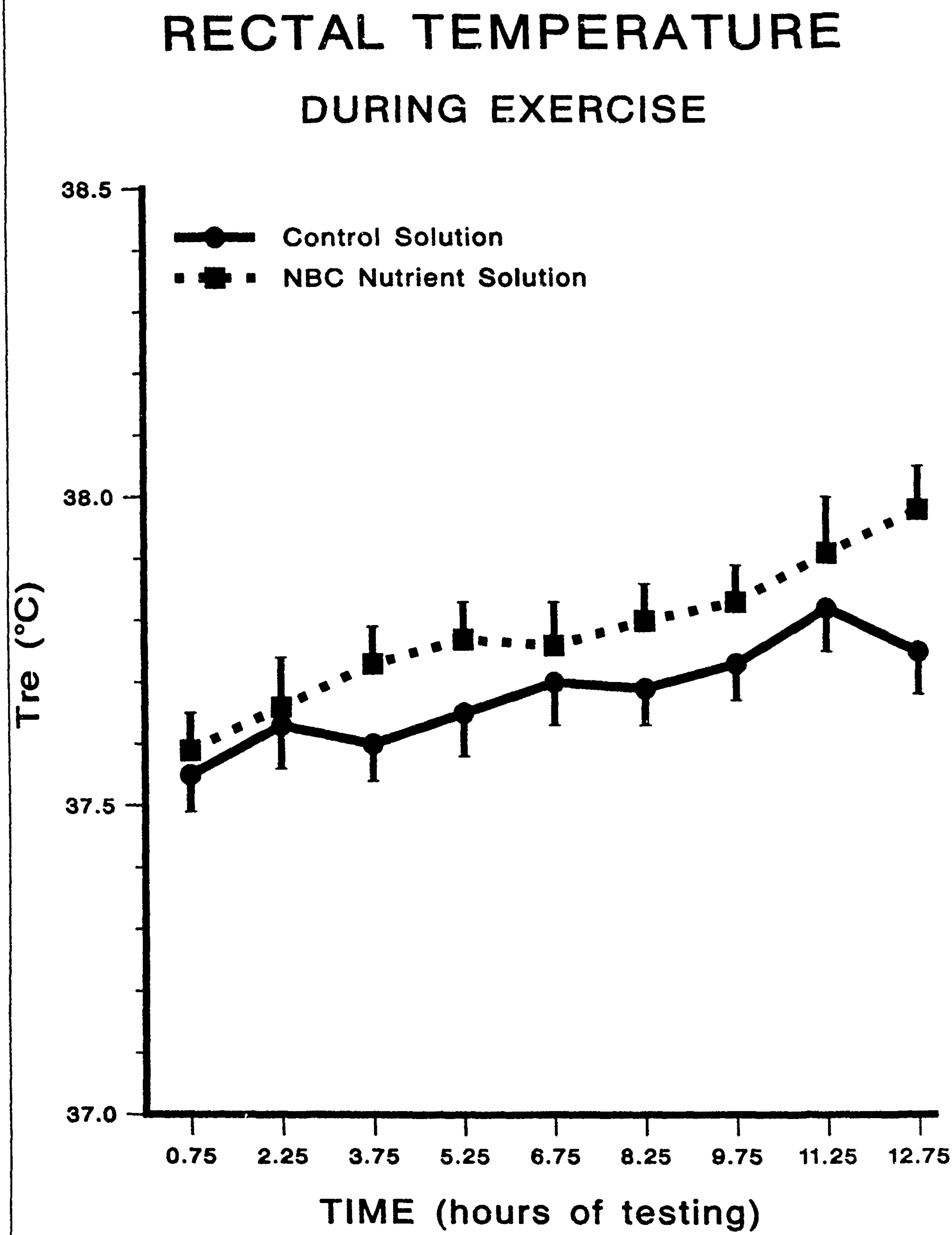

RECTAL TEMPERATURE
DURING EXERCISE
Control Solution
NBC Nutrient Solution
38.5
38.0
37.5
37.0
Tre (°C)
0.75
2.25
3.75
5.25
6.75
8.25
9.75
11.25
12.75
TIME (hours of testing)

Figure 2

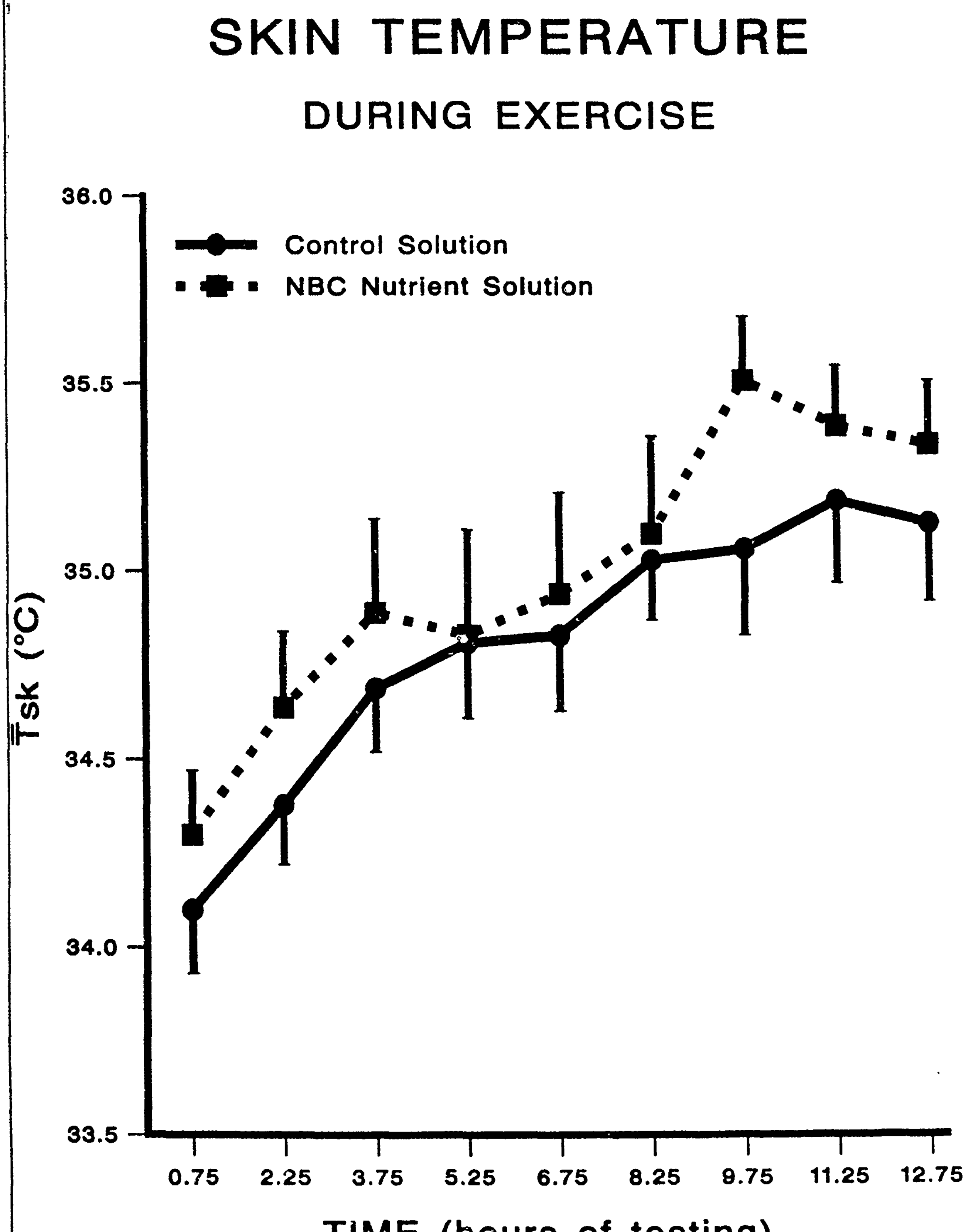

SKIN TEMPERATURE
DURING EXERCISE
Control Solution
NBC Nutrient Solution
36.0
35.5
35.0
34.5
34.0
33.5
T̄sk (°C)
0.75
2.25
3.75
5.25
6.75
8.25
9.75
11.25
12.75
TIME (hours of testing)

Figure 3

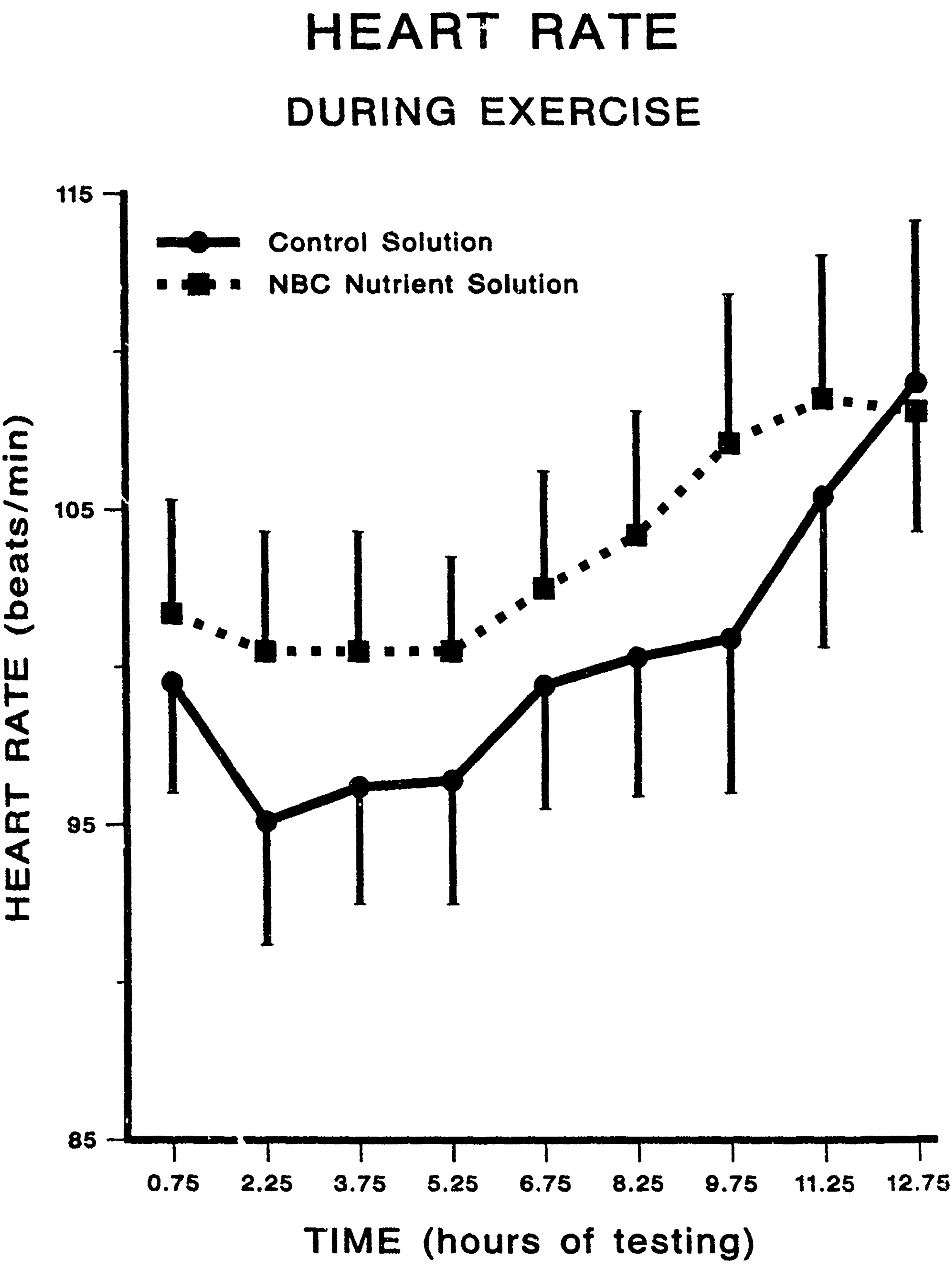

HEART RATE
DURING EXERCISE
Control Solution
NBC Nutrient Solution
HEART RATE (beats/min)
115
105
95
85
0.75
2.25
3.75
5.25
6.75
8.25
9.75
11.25
12.75
TIME (hours of testing)

Figure 4

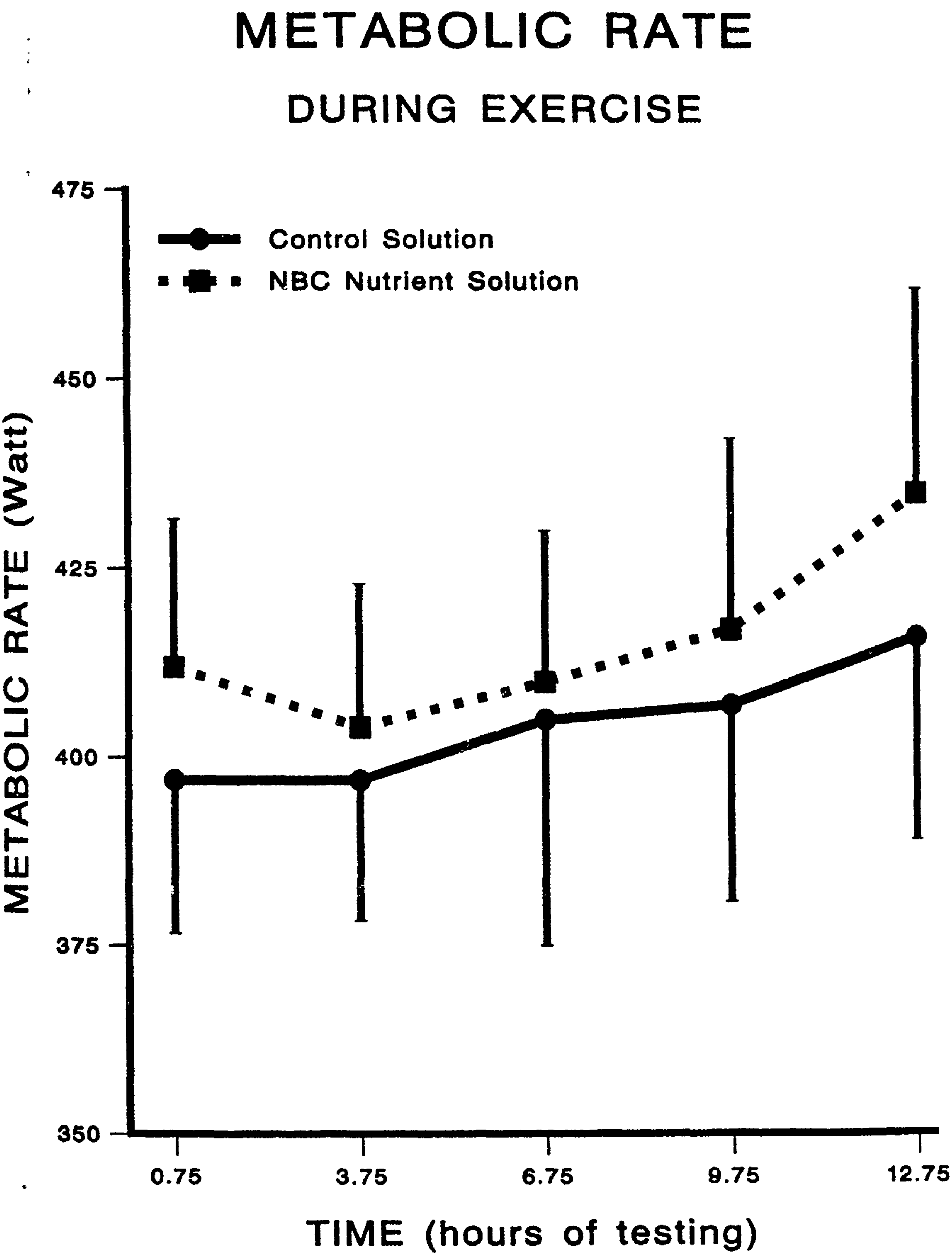
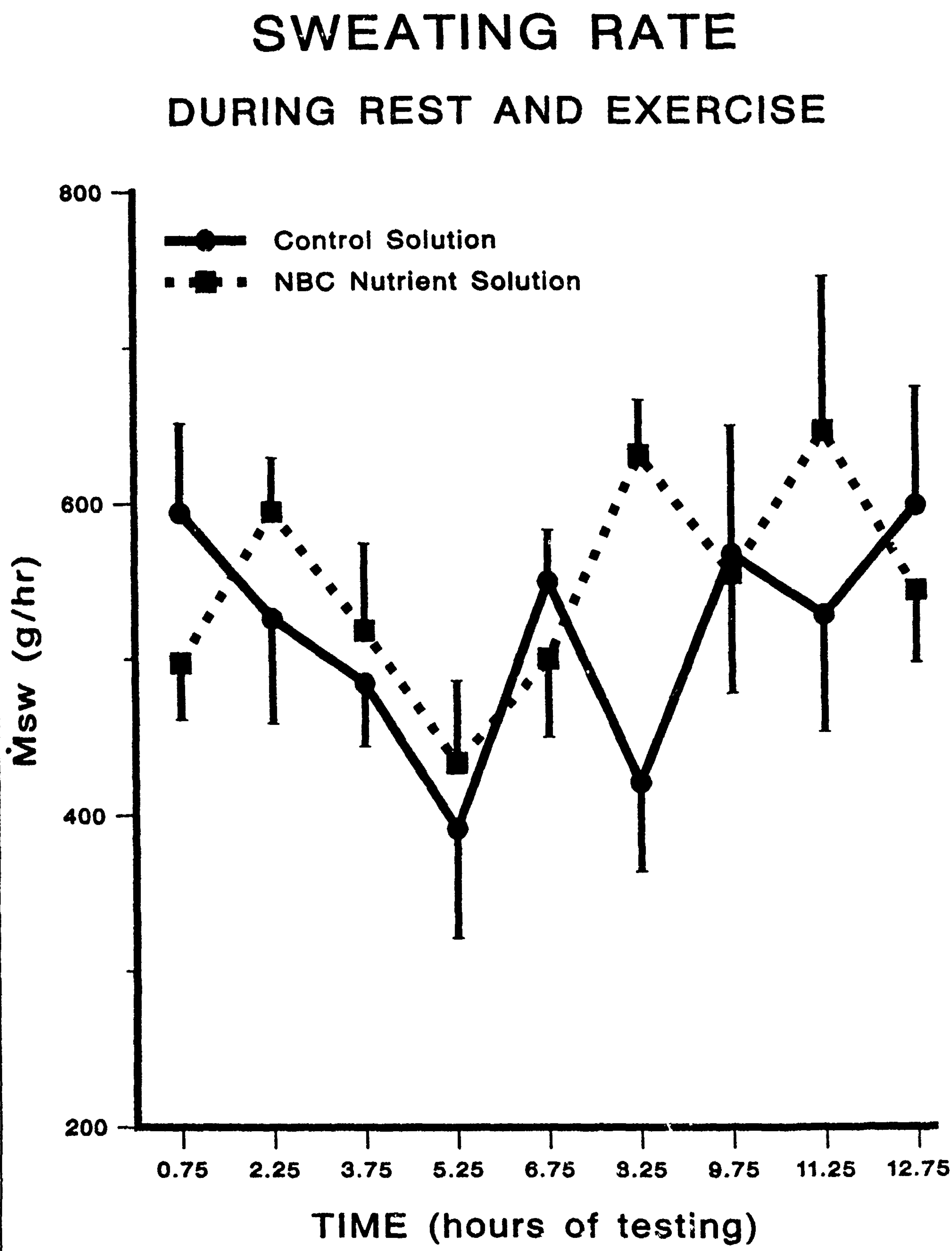

METABOLIC RATE
DURING EXERCISE
475
450
425
400
375
350
METABOLIC RATE (Watt)
Control Solution
NBC Nutrient Solution
0.75
3.75
6.75
9.75
12.75
TIME (hours of testing)

Figure 5



SWEATING RATE
DURING REST AND EXERCISE
800
600
400
200
Control Solution
NBC Nutrient Solution
Ṁsw (g/hr)
0.75
2.25
3.75
5.25
6.75
8.25
9.75
11.25
12.75
TIME (hours of testing)

PHYSIOLOGICAL ASSESSMENT

HYDRATIONAL STATUS

METHODS

Hydrational status was evaluated by monitoring hematocrit, hemoglobin, osmolality, Na^+, K^+, and Cl^- in the blood; by measuring body weight changes; and by measuring fluid consumption and elimination. Venous blood samples were collected from an indwelling Teflon catheter placed within a superficial forearm vein. A resting blood sample (14 ml) was taken after the subject stood for 20 minutes in the antechamber (20°C ambient temperature). Patency was maintained with heparinized saline; the catheter (1-ml of dead space) was flushed with 2 ml of blood before each exercise blood sample (5 ml) was obtained. Exercise blood samples were obtained 30 minutes into the second and every even-numbered exercise bout while the subjects continued to walk. A total of 130 ml of blood (5 ml x 13 samples x 2 repetitions) was collected from each volunteer by qualified personnel. There were 16 exercise bouts in 24 hours but 3 of the blood drawing times coincided with those for nutritional status so that the blood drawing was combined. Triplicate measurements were made for all blood variables. Standardized laboratory techniques were used to analyze blood for hemoglobin, hematocrit, total protein, sodium, potassium, and chloride. Plasma osmolality was measured by freezing point depression (Osmette A, Precision Systems).

Urine samples were collected and quantitatively analyzed for specific gravity, sodium, and potassium.

Statistical Analysis

Two-way analysis of variance (ANOVA) with repeated measures procedures were used to analyze the data for significant differences. Tukey's HSD post hoc tests were used to determine where the differences occurred. Data included all subjects except subject #6 (n=11). For the blood variables, data were analyzed at PRE, 5, 11, and 17 hours into the study. Data collected after the 17th hour were not statistically analyzed because of the decreasing sample size. The mean for the available subjects was substituted for missing data up to the 17th hour. Urine data were available PRE (overnight fast), and at 3, 6, 9, 12, 15, and 18 hours into the study. Urine data were statistically analyzed in the same manner as the blood data. The two-way ANOVA and post hoc tests allowed for comparisons over time for each solution, between solutions, and between solutions at each point in time.

RESULTS AND DISCUSSION

Results of this study generally indicated that the major indices of hydrational status were unaffected by consumption of the NBC Nutrient solution. For example, plasma sodium levels (Figure 1) and urinary specific gravity (Figure 2) manifested no significant differences at any of the respective sampling times between trials. Though the differences were not significant, plasma sodium levels for the NBC Nutrient solution trial were slightly higher than for the control trial which may have been due to the sodium content of the NBC Nutrient solution. Significant increments in either of these variables may be indicative of hypohydration or imminent

hypohydration. Nonetheless, statistical analyses of several other circulatory and urinary variables provided significant differences which are worthy of comment.

While total fluid intake and fluid intake per hour were not statistically different between trials, the data (Figure 3) indicated that there occurred a trend toward increased consumption during the NBC trial. This slightly increased consumption may explain the statistically significant ($p<0.05$), but physiologically minimal, decrements which occurred in hematocrit (Figure 4) during the NBC trial at 11 hours ($\bar{X}_{control}=44.18$, $\bar{X}_{NBC}=42.64$), at 14 hours ($\bar{X}_{control}=44.55$, $\bar{X}_{NBC}=42.64$) and at 17 hours ($\bar{X}_{control}=44.81$, $\bar{X}_{NBC}=42.92$). Hemoglobin levels generally reflected hematocrit values, and ranged from 14 to 16 g/dl in both trials. Interestingly, during these same intervals plasma total protein (Figure 5) levels were also significantly ($p<0.01$) lower during the NBC trial; again, however, absolute mean values (14 hours into study, $\bar{X}_{control}=7.84$ g/dl, $\bar{X}_{NBC}=7.40$ g/dl; 17 hours into study, $\bar{X}_{control}=7.90$ g/dl, $\bar{X}_{NBC}=7.49$ g/dl) are within the normal range for this variable. While plasma osmolality was not different between trials for the first three sampling intervals, by 8 hours into the study and at all sampling times thereafter, plasma osmolality was significantly ($p<0.05$) elevated during the NBC Nutrient solution trial (Figure 6). It is possible that the nutrient composition of the NBC Nutrient solution (Appendix 2) provided sufficient molecules and ions to the circulation during this trial to maintain the slightly elevated osmolality. It again should be emphasized, however, that even at the sampling time at which significant differences were observed, absolute differences in osmolality are minimal and during both trials the values are within the range of normal ($\bar{X}_{control}=284.2$,

$\bar{X}_{NBC}$=290.2) for euhydrated subjects. Blood potassium levels (Figure 7) were not affected by the exercise, the mild hyperthermia, or by the NBC Nutrient solution. Moderately increased potassium levels during either trial during the first 12 hours were probably due to release of potassium from contracting muscle cells. The study results confirmed the recommendations of the National Research Council Committee that the NBC Nutrient solution should not need potassium. The potassium values decreased after 11 hours in the NBC trial; this decrement could cause problems if the scenario continued. However, the three subjects who completed the 24-hour stress test while drinking the NBC Nutrient solution maintained normal potassium levels over the entire test interval.

As anticipated, urinary excretion of sodium during the control solution trial was significantly reduced as the test progressed (Figure 8) attesting to the rapidity with which homeostatic adjustments occur to preserve circulating sodium levels. In fact, consumption of the NBC Nutrient solution attenuated this marked decrement in urinary sodium excretion rate, thus, significant increments in urinary sodium excretion were observed at 9 hours ($p<0.05$), at 15 hours ($p<0.01$), and at 18 hours ($p<0.01$) during the NBC trial. For unexplained reasons, urinary potassium levels were somewhat lower in the first urine sample during the NBC trial, but following this, remained remarkably similar during the remainder of the sampling intervals (Figure 9).

CONCLUSIONS

From the point of view of hydration status, it may be concluded that both solutions maintained body hydration adequately. Even where changes occurred in circulating hydrational variables, statistical significance did not necessarily imply physiological significance. In fact, as noted above, circulatory variables during either trial remained in the range of normal for a healthy young male population. We have concluded from these data that under the specific test conditions described herein, both cool palatable flavored water and the NBC Nutrient solution were effective in maintaining hydration.

FIGURE LEGENDS

Figure 1. Plasma sodium levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 2. Urine specific gravity levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 3. Fluid intake per day and per hour during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 4. Hematocrit levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 5. Plasma total protein levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 6. Plasma osmolality levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 7. Blood potassium levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 8. Urinary sodium excretion during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$). The superscript 'a' indicates the SD value for the NBC Nutrient solution trial for that point of the study.

Figure 9. Urinary potassium excretion during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$). The superscript 'a' indicates the SD value for the NBC Nutrient solution trial at that point in the study.

Figure 1

NBC Nutrient Solution Study

Blood Sodium

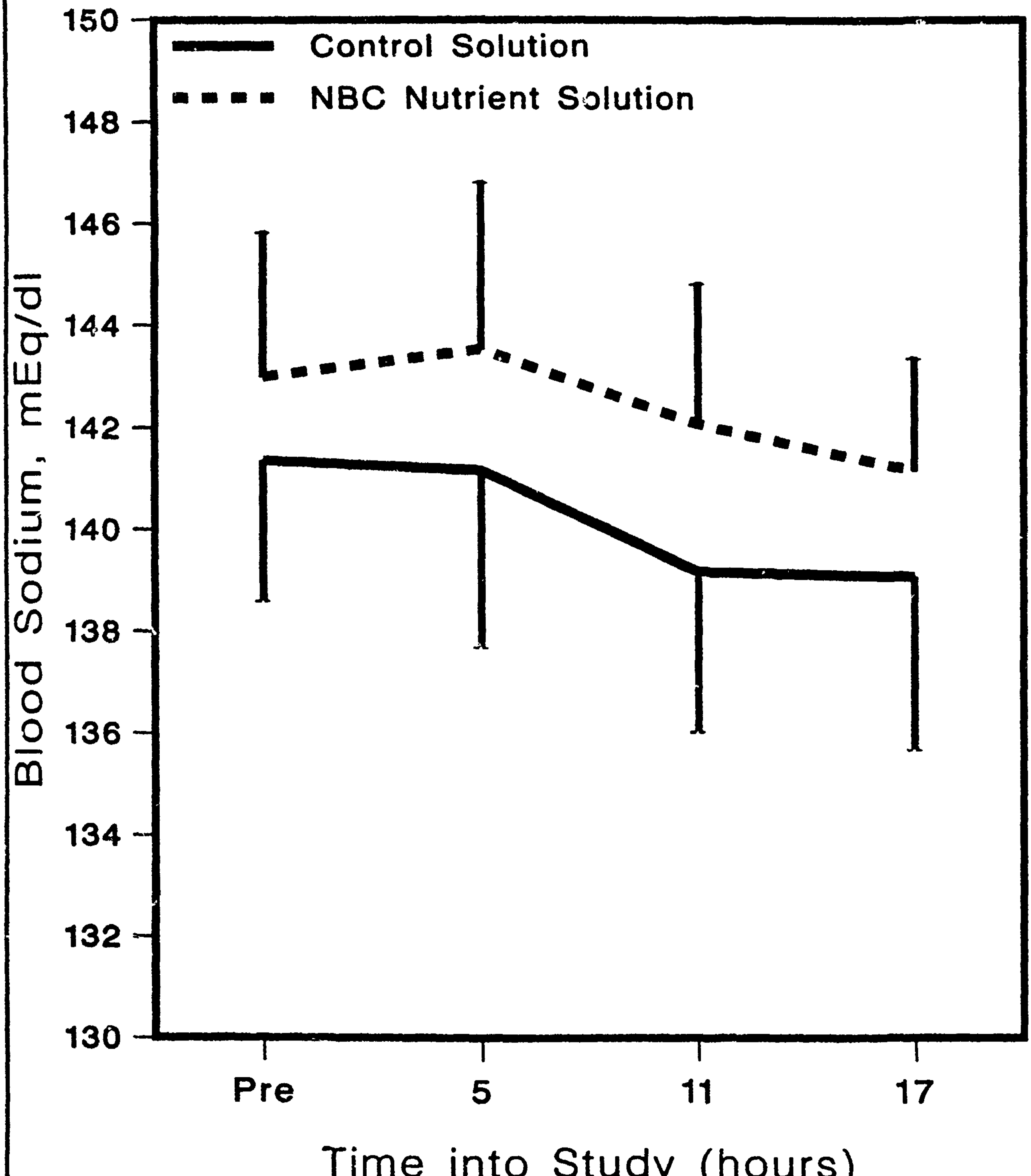


Figure 2

NBC Nutrient Solution Study

Urine Specific Gravity

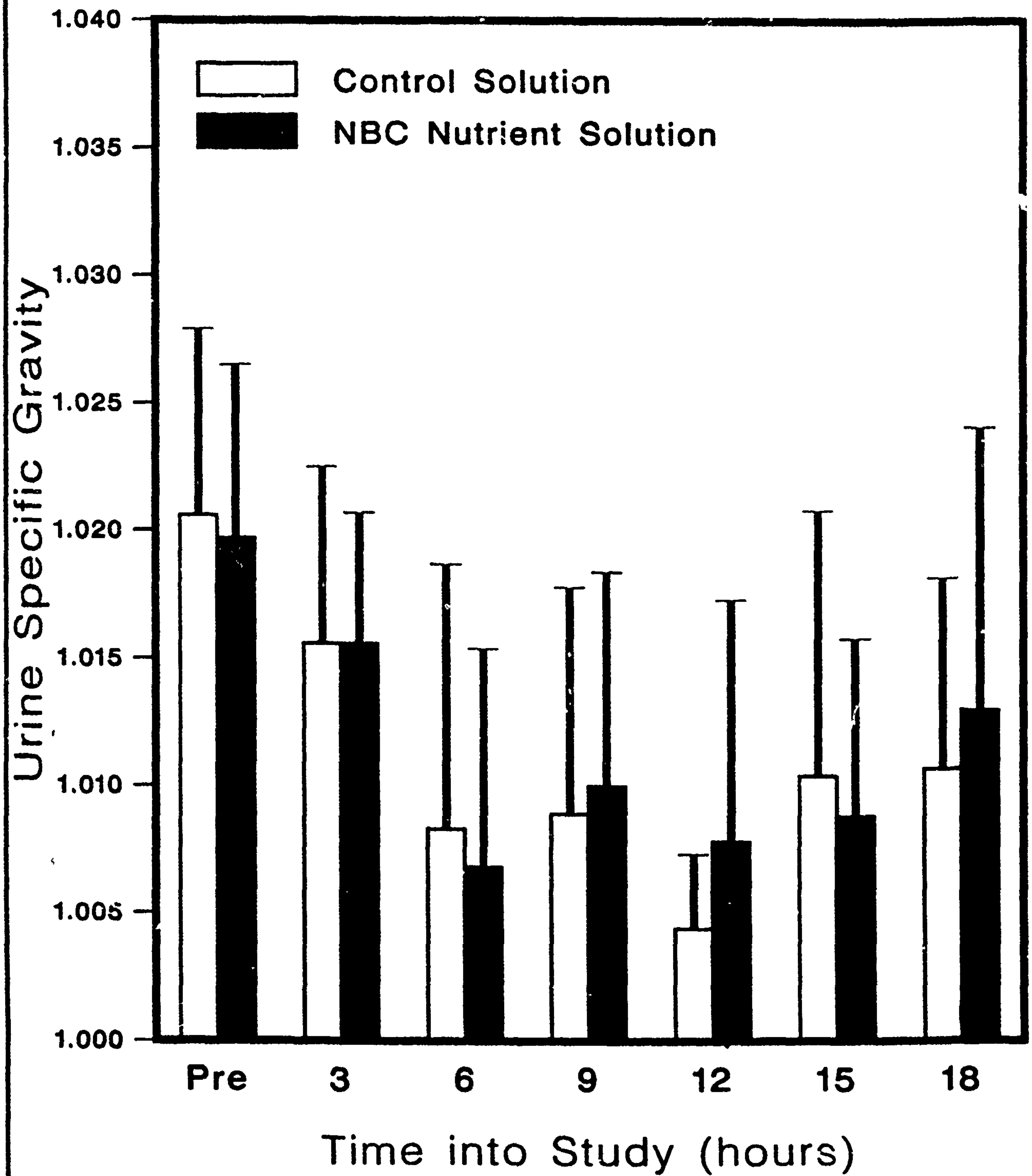
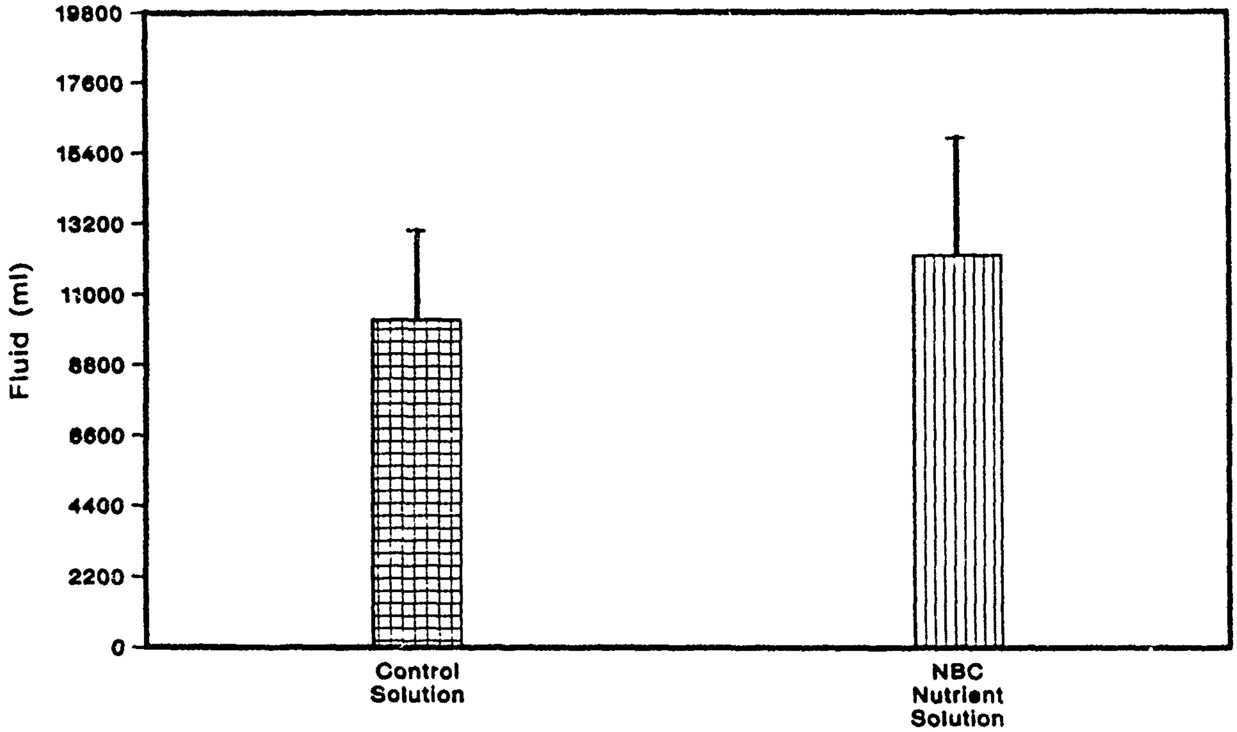


Figure 3

NBC Nutrient Solution Study

Total Fluid Intake



Fluid Intake / Hour

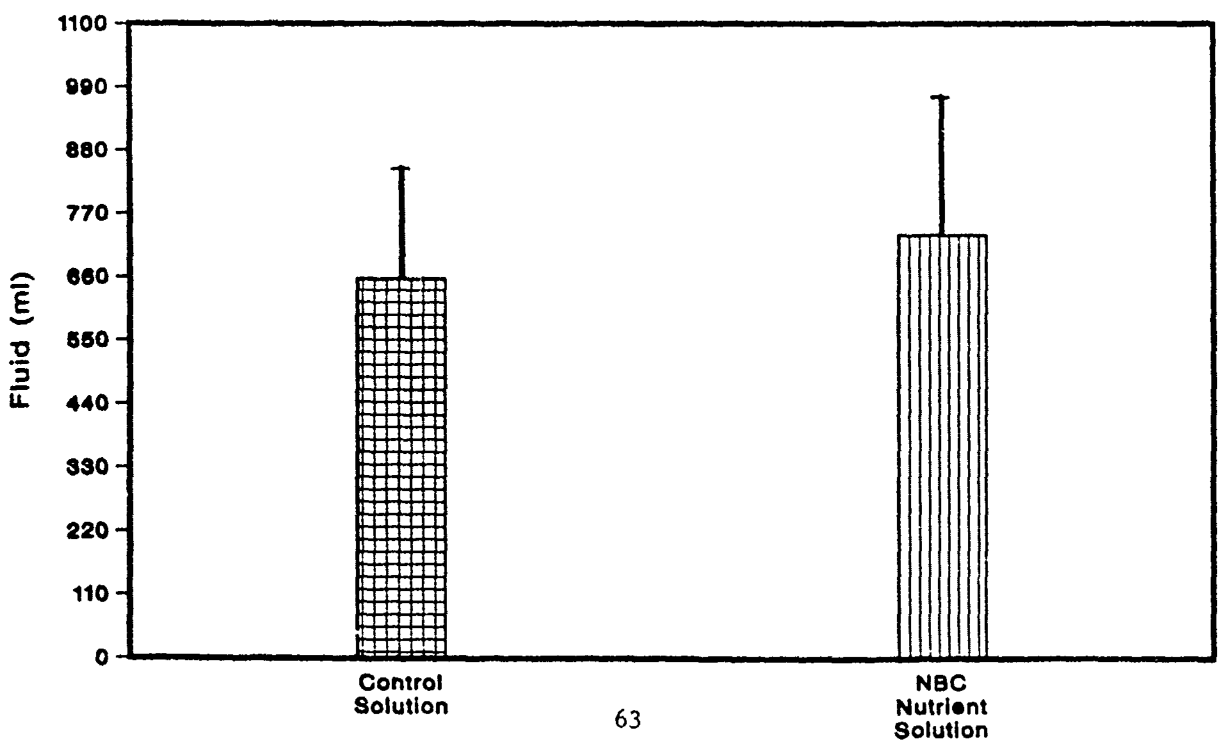


Figure 4

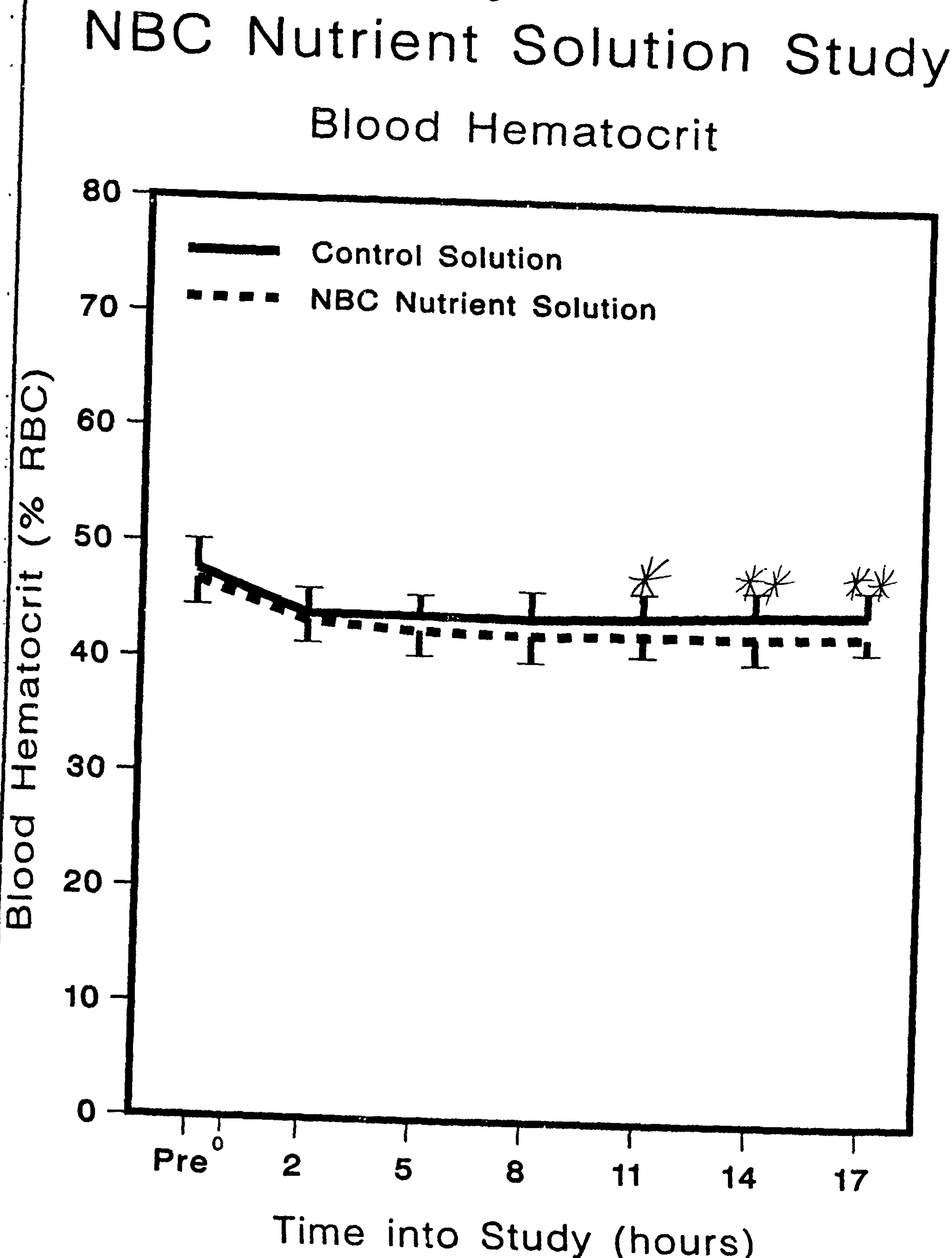

NBC Nutrient Solution Study
Blood Hematocrit
Control Solution
NBC Nutrient Solution
Blood Hematocrit (% RBC)
80
70
60
50
40
30
20
10
0
Pre
0
2
5
8
11
14
17
Time into Study (hours)

Figure 5

NBC Nutrient Solution Study

Blood Total Protein

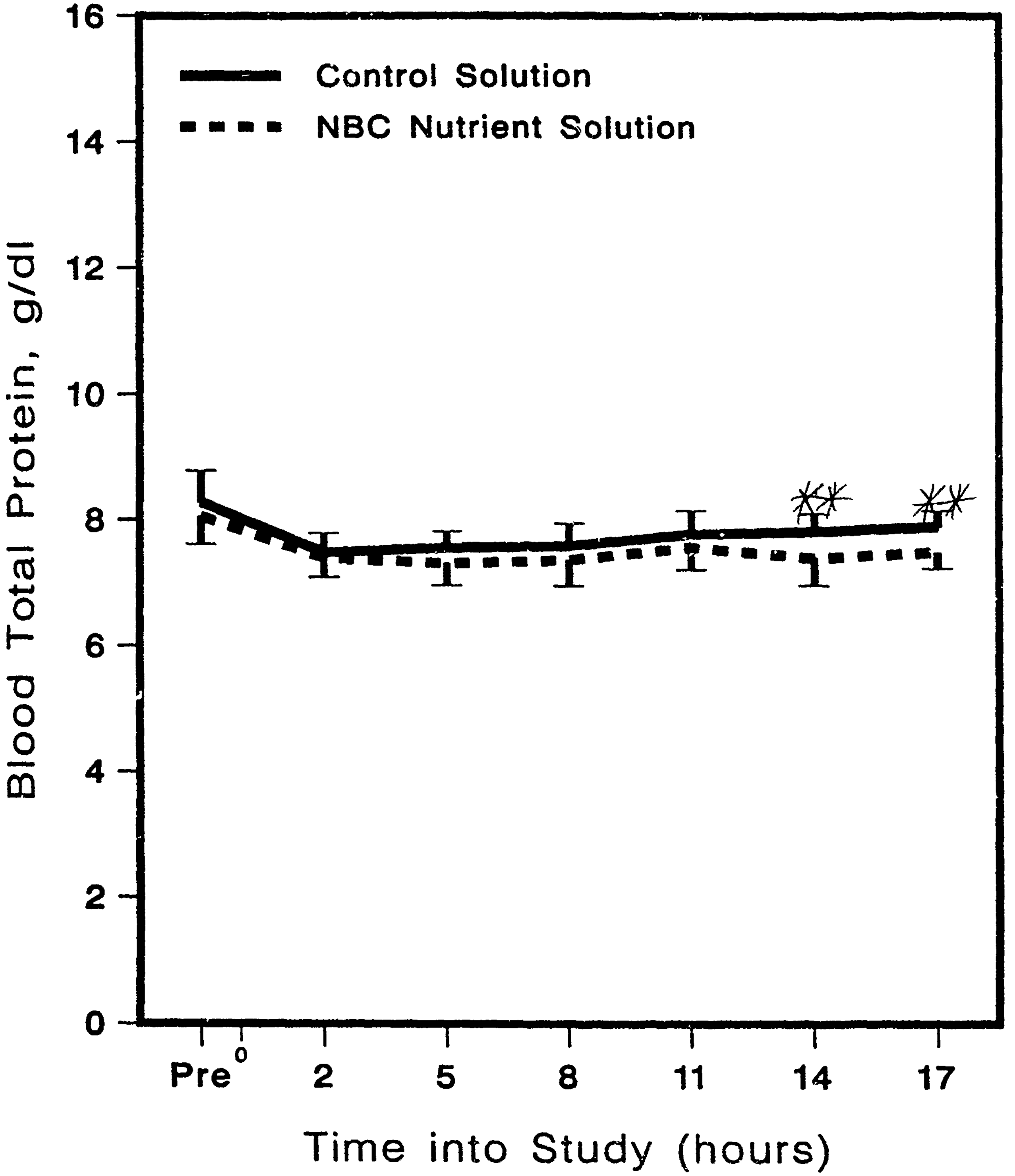
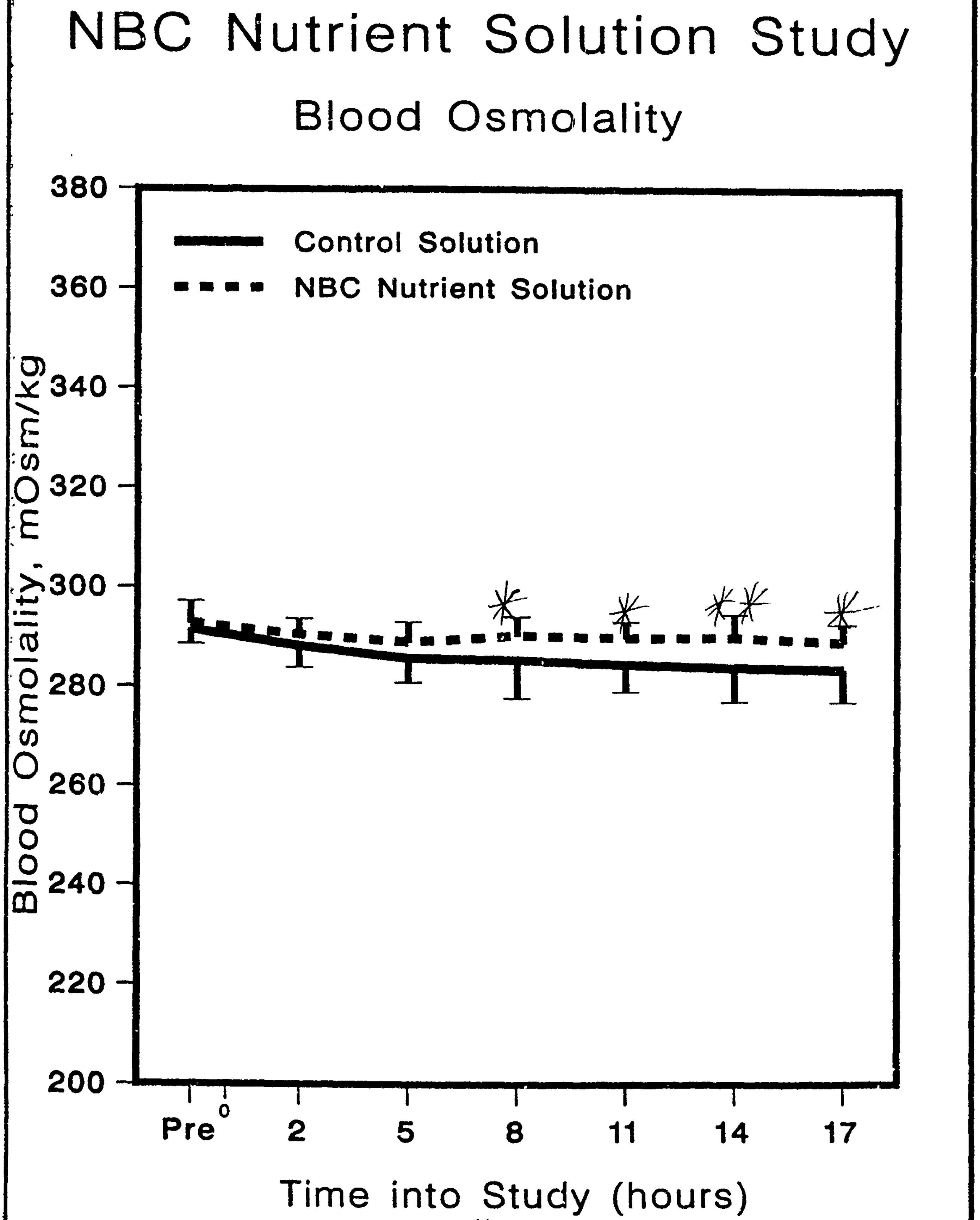
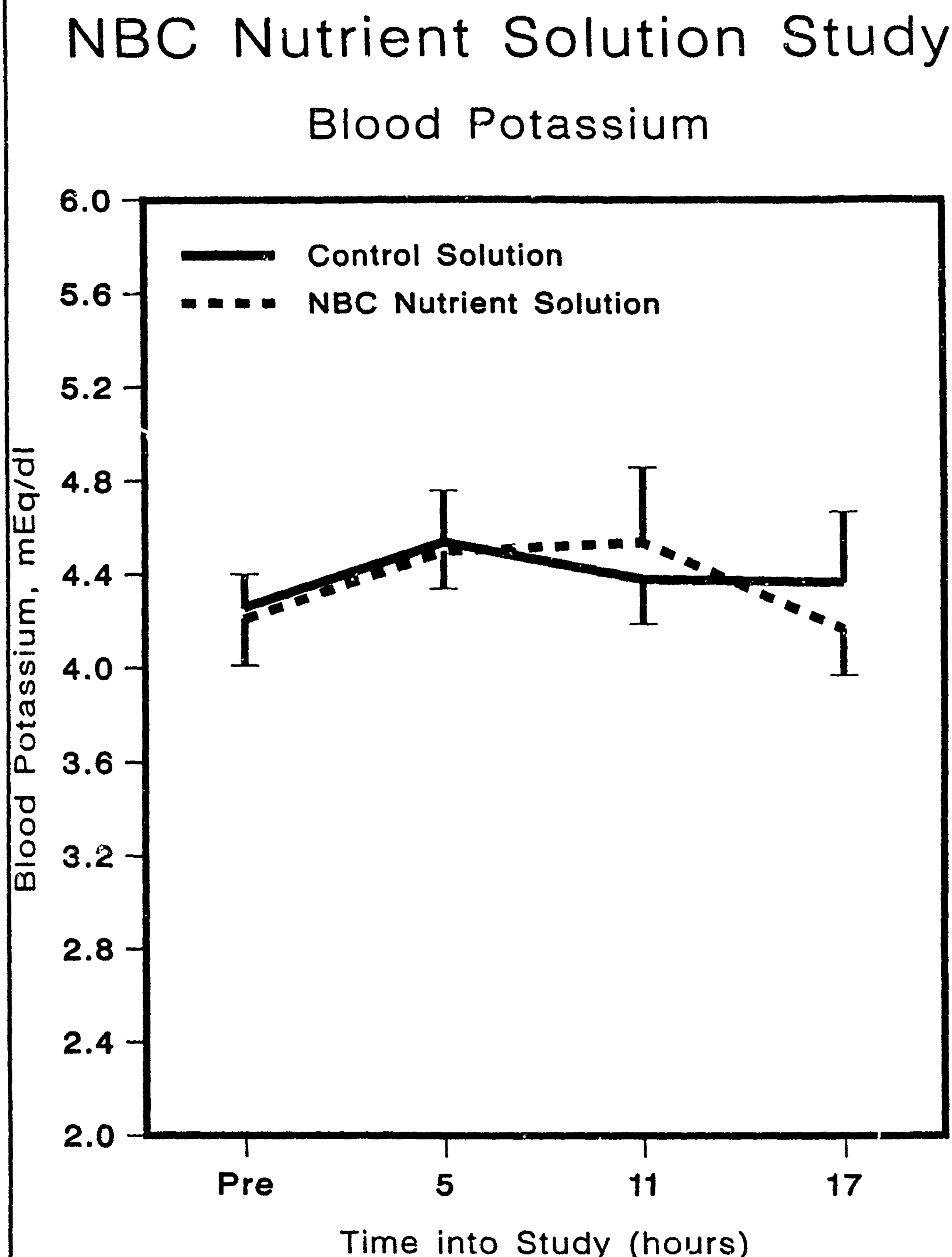


Figure 6



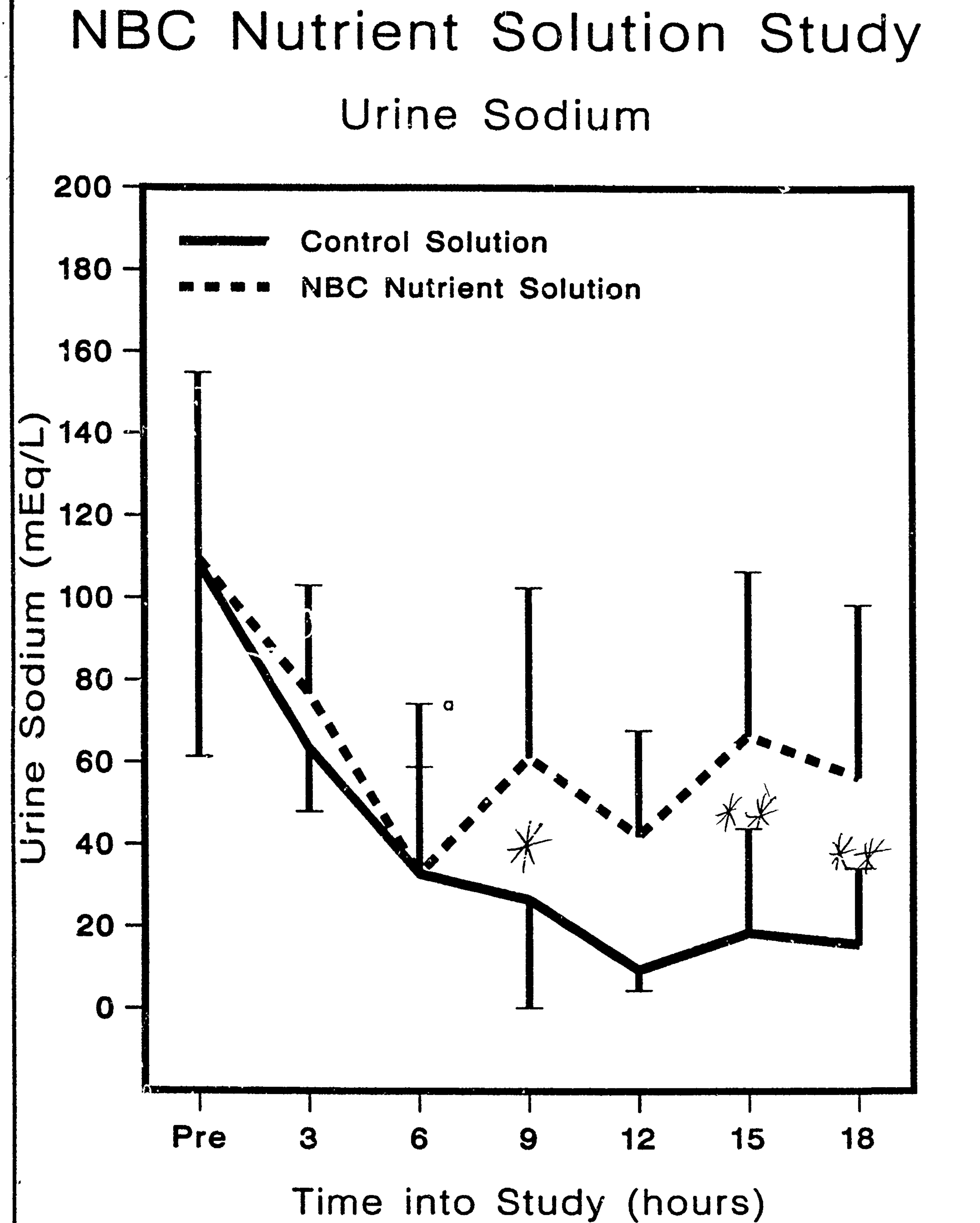
NBC Nutrient Solution Study
Blood Osmolality
Control Solution
NBC Nutrient Solution
380
360
340
320
300
280
260
240
220
200
Blood Osmolality, mOsm/kg
Pre
0
2
5
8
11
14
17
Time into Study (hours)

Figure 7



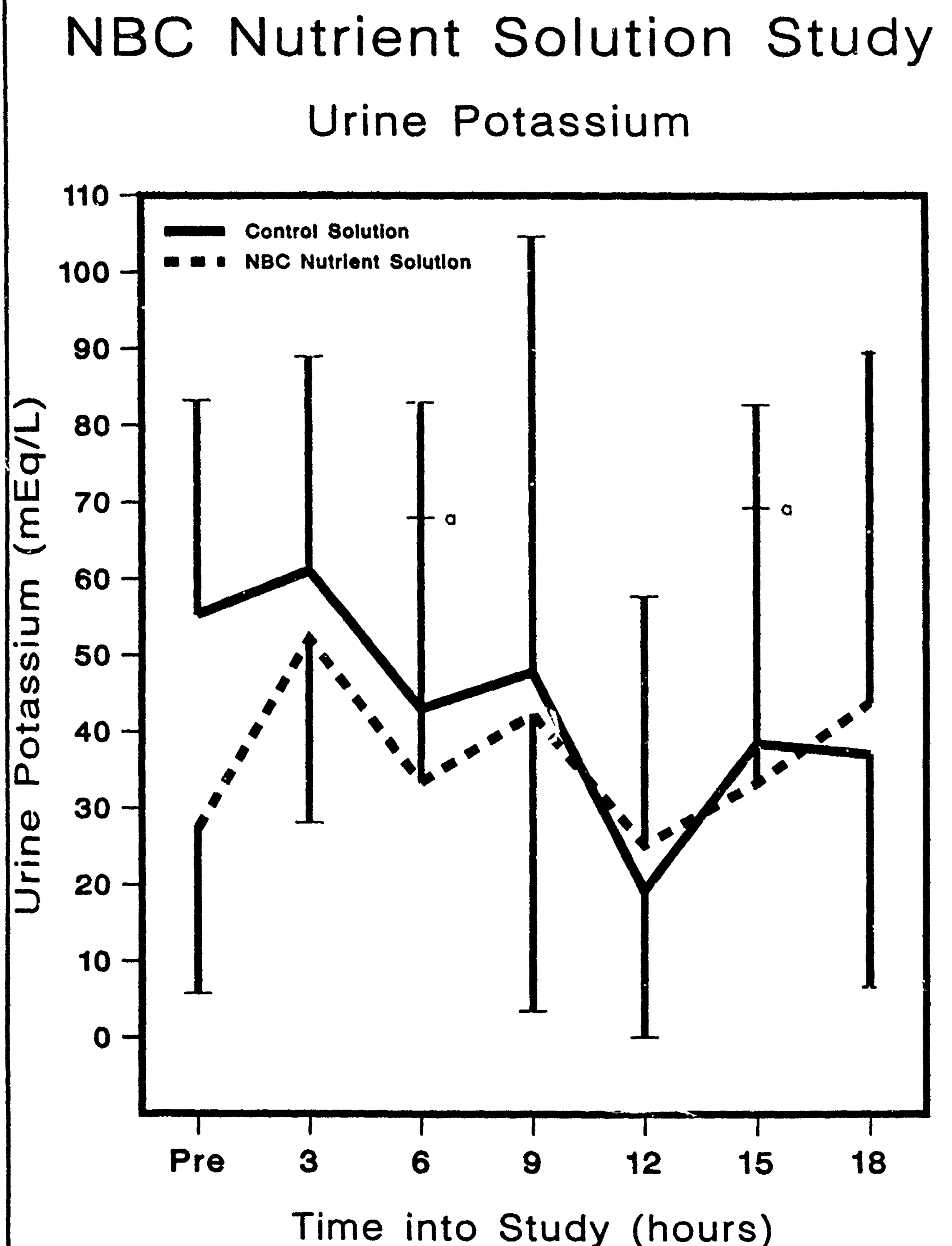
NBC Nutrient Solution Study
Blood Potassium
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.0
Blood Potassium, mEq/dl
Control Solution
NBC Nutrient Solution
Pre
5
11
17
Time into Study (hours)

Figure 8



NBC Nutrient Solution Study
Urine Sodium
Control Solution
NBC Nutrient Solution
Urine Sodium (mEq/L)
200
180
160
140
120
100
80
60
40
20
0
a
Pre
3
6
9
12
15
18
Time into Study (hours)

Figure 9



NBC Nutrient Solution Study
Urine Potassium
Control Solution
NBC Nutrient Solution
Urine Potassium (mEq/L)
110
100
90
80
70
60
50
40
30
20
10
0
a
a
Pre
3
6
9
12
15
18
Time into Study (hours)

PHYSIOLOGICAL ASSESSMENT

NUTRITIONAL STATUS

METHODS

Nutritional status was evaluated using biochemical indices in blood and urine. About 14 ml of venous blood was collected prior to the start of the test (PRE) and at the 5th, 11th, 17th, and 23rd hours. The following indicators of nutritional status were analyzed: Blood Urea Nitrogen (BUN), Free Fatty Acids, Glucose, Lactate, Albumin, Ketones, and Creatinine. All blood analyses were done by Smith Kline Laboratories except for plasma lactate (Model 23 Lactate Analyzer YSI) and blood ketones (Acetest reagent tablets). Urine samples were obtained as described in the Hydration Status section. Urine ketones were analyzed using the N-Multistix reagent strips.

Statistical Analysis

The BMDP programs for two-way analysis of variance (ANOVA) with repeated measures were used to analyze the data for significant differences. Tukey's HSD *post hoc* tests were used to determine where the differences occurred. Data included all subjects except subject #6 (n=11). The mean for the available subjects was substituted for missing data up to the 17th hour. Data collected after the 17th hour were not included in the analyses because the decrease in sample size was too drastic. Comparisons were analyzed over time for each solution, between solutions, and between solutions at each point in time. Data are presented as mean$\pm$SD.

RESULTS

Blood Albumin

Blood albumin levels were significantly different ($p<0.01$) between the two solutions but values for both fluid trials stayed well within the normal range (4 to 5 g/dl) for the duration of the study (Figure 1). Values for the two fluid trials followed similar patterns of increases and decreases. Both showed the sharpest decline between the PRE and 5th hour (Control 4.95±0.29 to 4.67±0.17 g/dl; NBC 4.84±0.20 to 4.50±0.18 gm/dl). The albumin levels for the NBC Nutrient solution trial were consistently lower than comparable levels for the control solution with significant differences occurring only at the 17th hour ($p<0.01$) which is consistent with observations for total protein.

Elevated blood albumin levels are clinical indicators of dehydration while lower values are observed in malnutrition (1). The slightly higher values of blood albumin during the control trial may indicate that subjects in the NBC Nutrient solution trial remained slightly more hydrated than those in the control trial.

Blood Glucose

There were significant differences ($p<0.05$) in blood glucose between the two fluid conditions, at the 17th hour (Figure 2), and over time. Blood glucose during the control trial manifested a greater overall decline with levels in the 11th and 17th hours significantly ($p<0.05$) lower than the PRE

value. The glucose level during the NBC Nutrient solution trial did not decrease significantly over time. The significant increase in the NBC Nutrient solution trial at the 17th hour may be an artifact of statistical analysis. The one large value that was obtained for one subject and the loss of several subjects with lower blood glucose values may have artificially increased the mean at this point in time.

Blood Lactate

Blood lactate levels decreased significantly for both trials after the PRE blood draw (Figure 3) but there were no significant differences between the two fluid trials.

Free Fatty Acids, Respiratory Exchange Ratio, and Ketones

The most significant metabolic differences ($p<0.001$) seen between the two test solution trials occurred in the levels of blood free fatty acids (FFA) (Figure 4). Depending on nutritional status, normal concentrations range between 0.3 to 0.5 mEq/liter; higher values usually occur in a state of fasting, exercise, or malnutrition. FFA levels in both fluid trials were below the normal range at the time of the first blood sample (PRE), probably due to the previous ingestion (within 2 hours) of a meal. During the control trial there was a greater increase of FFA over the duration of the study, from a mean starting level of 0.27 ± 0.06 mEq/l to a mean of 1.45 ± 0.48 mEq/l about 17 h into the study ($p<0.01$), indicating a reliance on FFA for energy production. The subjects in the NBC Nutrient solution trial manifested a more gradual increase from a starting point of 0.25 ± 0.09 mEq/l to a maximum

value of only 0.65±0.15 mEq/l ($p<0.01$) at the 11th hour before leveling off in the 17th hour. Consideration of FFA levels indicated that the glucose in the NBC Nutrient solution may have decreased the need for fat oxidation to sustain energy requirements. This increased reliance on FFA for energy was also reflected in the Respiratory Exchange Ratio (RER) (Figure 5). The RER values were significantly different ($p<0.001$) between trials and over time. During the NBC Nutrient solution trial carbohydrate was being metabolized from the NBC Nutrient solution resulting in a higher RER whereas glucose was not exogenously available during the control trial. The decreasing RER over time indicated an increased reliance on fat for fuel. Another indicator of increased fatty acid oxidation was the appearance of ketones in the urine (2,3). While ketones were not found in any of the blood samples taken during either trial, they were found in the urine of the subjects (Tables 1 and 2). In the NBC Nutrient solution trial, 2 Subjects (#9 & #12) showed traces of ketones at the time they dropped out of the test. During the control trial, 7 of the 11 subjects showed urinary ketones at some point after nine hours of testing.

Blood Urea Nitrogen and Creatinine

The Blood Urea Nitrogen (BUN) levels for both trials were within the normal range (8 to 25 mg/dl) and not significantly different. For the NBC trial the BUN significantly ($p<0.01$) declined from the PRE value to the 5th hour dropping from 16.55±2.94 mg/dl to 11.82±3.06 mg/dl before stabilizing (Figure 6). Significant differences were observed in the BUN values between the two fluid trials at the 11th and 17th hours, but the values were still within the normal range. Another indicator of nitrogen status is blood

creatinine levels (Figure 7). Creatinine is a breakdown product of skeletal muscle creatine. Increases in circulating creatinine (0.7 to 1.4 mg/dl) can be provoked by dehydration, physical work, and extreme temperatures. While the NBC Nutrient solution did not affect creatinine levels, intermittent exercise in the heat caused a significant increase ($p<0.05$), from PRE to hour 17. Increased circulating creatinine was probably due to nitrogen catabolism in the absence of sufficient calories. Physiologically significant differences in creatinine levels were not observed in either trial.

DISCUSSION

The sources of carbohydrate in the NBC Nutrient Solution were maltidextrins (10.3960 g/l) and fructose (14.4372 g/l). There remains a great deal of controversy as to which carbohydrate source provides the most beneficial results. Lamb (4) summarized the literature comparing the use of glucose, fructose, or glucose polymers, with and without electrolytes, and reported that carbohydrate drinks regardless of the carbohydrate source maintain blood glucose levels and are often associated with better performance. Optimal levels or form of carbohydrate are not known at this time (4).

Glucose levels were above normal fasting levels for both fluid trials at the beginning of the tests. This was anticipated since the subjects had eaten fairly substantial meals ($\bar{X}$=953 kcal) just two hours prior to the test. The literature (5-7) suggests that eating within 15 to 45 minutes of the initiation of high intensity exercise may cause a decreased endurance time

because the glucose-stimulated insulin secretion lowers endogenous blood glucose levels. However, the present study was designed to simulate actual field conditions in which personnel might well have completed a meal before the onset of an emergency situation. The results of this study confirmed previous work (8,9) that showed that blood glucose may not drop precipitously after pre-exercise glucose feeding because of the slower rate of glucose removal by skeletal muscle during prolonged low intensity exercise.

Ingestion of carbohydrate during exercise can prevent hypoglycemia (10) potentially by delaying glycogen depletion (11,12). Controversy exists as to the importance of carbohydrate drinks in long term exercise (13-16). These drinks are of benefit when consumed during moderate and high intensity anaerobic exercise (17-20) because they provide glucose which is the principal source of energy for this type of exercise. The beneficial effects of carbohydrate feeding during light-moderate intensity aerobic exercise, such as in the present study, may be negligible because the exercise is fueled by lipid oxidation with a very small demand for carbohydrate (21).

The present study supported the conclusions of Lamb (4) that there were no significant differences between water and a carbohydrate drink in regard to weight loss or blood lactate. In both studies, blood glucose was greatest for the carbohydrate drink. The subjects in the present study consumed about 313.4 g CHO/day [(0.7389 l/h x 17.1 h) x 24.8 g CHO/l] while drinking the NBC Nutrient Solution. The quantity of carbohydrate consumed during the NBC Nutrient solution trial was more than the 150-200 g/day that is required to meet the requirements of the CNS, eye lens, and erythrocytes (22-24).

NUTRITIONAL STATUS

The ability of the NBC Nutrient solution to replenish muscle glycogen could not be answered with this test. Costill et al. (25) reported that a diet containing 525 g carbohydrate in 3000 kcal would be needed to replenish depleted muscle glycogen stores in subjects running 2 h/day at 70% $\dot{V}O_2max$. The NBC Nutrient solution only provided about half that amount of carbohydrate; however the subjects in the present study were not working at 70% $\dot{V}O_2max$ and therefore may not have experienced a large depletion in their muscle glycogen stores. Low intensity exercise (ie. 30-50% $\dot{V}O_2max$) relies mainly upon fat for fuel and muscle glycogen is consumed at a slower rate requiring 5-10 hours of contiruous activity for depletion (26,27). Since the subjects in the present study were engaged in a low intensity activity (29% $\dot{V}O_2max$) with intermittent rest periods, muscle glycogen stores were probably not reduced markedly. The amount of glucose ingested from the NBC Nutrient solution may have been sufficient to keep muscle glycogen stores from being depleted. Evidence to support this view could be found in the data on urinary ketones. Ketones are not usually produced until body glycogen stores are nearly depleted. The subjects drinking the NBC Nutrient solution generally did not spill ketones into their urine whereas 7/11 subjects produced ketones when drinking the control solution. Researchers have suggested that maintaining muscle glycogen is important for prolonging endurance. The NBC Nutrient solution did not significantly increase performance even though the mean endurance time was increased by one hour.

Lactate levels were of interest in this study. Anaerobic or high-intensity exercise precludes adequate oxygen delivery for fat oxidation; thus glucose, which can be anaerobically metabolized to lactate in glycolysis, is

utilized. Most of the previous studies examined subjects performing moderate to heavy exercise, and under these conditions, plasma lactate levels increase. The subjects in the present study were working at 29% $\dot{V}O_2max$ which is considered light activity (21) and well below the anaerobic threshold. This could account for the lack of perceivable increases in lactic acid levels.

If the nutritional data are examined for trends, it becomes obvious that a changeover in energy substrates occurred at approximately 12 hours into the study during both fluid trials. Ketones were appearing in the urine, blood glucose and lactate levels were stabilizing, and FFA in the blood were leveling off, especially in the NBC trial. The RER values were decreased over time for both trials. The ratio of carbon dioxide production to oxygen consumption (RER) averages 0.82 (28) under sedentary conditions when more carbohydrate is used than fat as the body's fuel. During steady-state submaximal exercise (as in the present study), the RER decreases indicating increased fat oxidation. The increasing FFA levels were expected for the subjects ingesting the control solution because of the lack of nutritional replenishment. Free fatty acids were at their highest levels for the NBC trial after 11 hours, but the rate leveled off during the next hours which could indicate that the body may have reached an equilibrium in its use of FFA for energy. Ketones had appeared in the urine of 7 subjects during the control trial between the 9th and 16th hours - another indicator of a switch in energy substrates to fatty acids. Of the subjects who did not show any signs of ketones, two subjects had dropped out of the study by the 12th hour (#1 & #8) and the other 2 subjects (#4 & #5) had the largest breakfasts (1100

and 1475 kcal) on the test day. Most of the other subjects consumed a third to a half that number of calories. The maintenance of blood glucose levels and the delayed appearance of ketones in the urine of subjects ingesting the NBC solution remain the only notable physiological differences between treatments.

A diet deficient in carbohydrate eventually can deplete muscle and liver glycogen stores and subsequently affect performance in submaximal endurance activities (25,29). When carbohydrate reserves are reduced, protein is used for carbohydrate synthesis. Under extreme conditions, there is a significant reduction in lean body mass and thus an added demand on the kidneys which must excrete the nitrogen (21). Ammonia is released during deamination of protein, converted to urea (30), and excreted by the kidneys. If a person does not eat any protein, then 20-30 g/day of body protein is obligatorily degraded into amino acids, deaminated, and oxidized (30). Except for excess protein in the diet or the 20-30 g/day obligatory protein degradation, the body uses available carbohydrate and fat for energy as long as these are available.

The NBC Nutrient solution was expected to provide carbohydrate to counteract hypoglycemia. Carbohydrate is essential for proper functioning of the CNS. Under normal conditions and in short-term starvation, the brain uses blood glucose almost exclusively but has no stored supply of this nutrient (21,30). If blood glucose falls to dangerously low levels, the metabolism of the CNS becomes depressed. As the blood glucose level falls below 50-70 mg%, the CNS becomes excitable, hallucinations may result, and extreme nervousness is exhibited (30). Other symptoms of modest reductions

in blood glucose include feelings of weakness, hunger, and dizziness which impairs exercise performance and may partially explain the fatigue associated with prolonged exercise (21). Sustained and profound low blood sugar can cause irreversible brain damage (21,30). Since hypoglycemia did not develop, it was not possible to assess the effects of either solution on hypoglycemia.

Ketosis occurs most commonly in starvation when stores of liver glycogen have been depleted (31). Acetoacetate, B-hydroxybutyrate, and acetone are the ketone bodies which are formed in the liver (31,32) during the breakdown of FFA and oxidized during food deprivation by extra hepatic tissues (muscle, kidney, heart, brain, and adrenal glands) (31,32). Ketosis occurred at about the 13th hour in a majority (7/11) of the subjects during the control trial. While drinking the NBC Nutrient solution, only two subjects showed urinary ketones and this occurred at the time that they withdrew from the 24-h test (14th and 24th hours). The NBC solution was successful in delaying the appearance of ketones compared to the control solution. As starvation or low carbohydrate intake progresses, the CNS switches from glucose to ketones as its primary fuel. The human brain can utilize ketone bodies for up to 20% of its total energy requirements after an overnight fast, 60% after an 8-day fast, and about 80% after a 40-day fast (32). Delaying the appearance of ketones may allow the CNS time to adapt to using large amounts of ketone bodies as fuel (33,34). If ketones are produced faster than they can be used, metabolic acidosis can develop and lead to hyperventilation, increasing drowsiness, and unconsciousness (32).

CONCLUSIONS

1. Both solutions were able to maintain blood glucose within normal levels for the entire study but the blood glucose levels were consistently higher for the NBC solution trial.

2. The low intensity of the exercise (29% $\dot{V}O_2max$) did not deplete blood glucose to hypoglycemic levels with either solution therefore it is not possible to assess the effects of hypoglycemia on cognitive performance or vigilance.

3. The NBC Nutrient solution was able to provide sufficient carbohydrate to attenuate ketosis.

4. Free fatty acids were an important fuel source for subjects in both solutions within the first 5 hours of the study even though the subjects had eaten about 900 kcal (140.7 and 156.4 g CHO) prior to the start of the study.

5. Elevations in creatinine and BUN values in the control trial relative to the NBC Nutrient solution trial indicated that protein catabolism was occurring.

REFERENCES

1. Thiele VF. Clinical Nutrition, 2nd ed. St Louis:CV Mosby Co., 1980.

2. Taylor HL, Henschel A, Mickelsen O, Keys A. Some effects of acute starvation with hard work on body weight, body fluids and metabolism. J Appl Physiol 1954;6:613-623.

3. Drury DR, Wick AN, MacKay EM. The action of exercise on ketosis. Am J Physiol 1941;134:761-768.

4. Lamb DR, Brodowicz GR. Optimal use of fluids of varying formulations to minimize exercise-induced disturbances in homeostasis. Sports Med 1986;3:247-274.

5. Bonen A, Malcolm SA, Kilgour RD, MacIntyre KP, Belcastro AN. Glucose ingestion before and during intense exercise. J Appl Physiol 1981;50:766-771.

6. Costill DL. Sweating: Its composition and effects on body fluids. In: Milvy P, ed. The marathon: Physiological, medical epidemiological, and psychological studies. New York: New York Academy of Sciences, 1977: 160-174.

7. Levine L, Evans WJ, Cadarette BS, Fisher EC, Bullen BA. Fructose and glucose ingestion and muscle glycogen use during submaximal exercise, J Appl Physiol 1983;55:1767-1771.

8. Ahlborg G, Felig P. Substrate utilization during prolonged exercise preceded by ingestion of glucose. Am J Physiol 1977;233:E188-E194.

9. Brooke JD. Lowered blood glucose with human fasting, exercise and carbohydrate diet. Nutr Reports Int 1981;24:1279-1283.

10. Foster C, Costill DL, Fink WJ. Gastric-emptying characteristics of glucose and glucose polymer solutions. Res Q Exer Sport 1980;51:299-305.

11. Ahlborg B, Bergstrom J, Ekelund LG, Hultman E. Muscle glycogen and muscle electrolytes during prolonged physical exercise. Acta Physiol Scand 1967;70:129-140.

12. Costill DL, Bennett A, Branam G, Eddy D. Glucose ingestion at rest and during prolonged exercise. J Appl Physiol 1973;34:764-769.

13. Felig P, Cherif A, Minagawa A, Wahren J. Hypoglycemia during prolonged exercise in normal men. N Engl J Med 1982; 306:895-900.

14. Fielding RA, Costill DL, Fink WJ, King DS, Hargreaves M, Kovalski JE. Effect of carbohydrate feeding frequencies and dosage on muscle glycogen use during exercise. Med Sci Sports Exerc 1985;17:472-476.

15. Krzentowski G, Jandrain B, Pirnay F, Mosora F, Lacroix M, Luyckx AS, Lefebvre PJ. Availability of glucose given orally during exercise. J Appl Physiol 1984;56:315-320.

16. Van Handel PJ, Fink WJ, Branam G, Costill DL. Fate of ^{14}C glucose ingested during prolonged exercise. Int J Sports Med 1980;1:127-131.

17. Hargreaves M, Costill DL, Coggan A, Fink WJ, Nishibata I. Effect of carbohydrate feedings on muscle glycogen utilization and exercise performance. Med Sci Sports Exerc 1984;16:219-222.

18. Costill DL, Miller JM. Nutrition for endurance sport: Carbohydrate and fluid balance. Int J Sports Med 1980;1:2-14.

19. Coyle EF, Hagberg JM, Hurley BF, Martin WH, Ehsani AA, Holloszy JO. Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. J Appl Physiol 1983;55:230-235.

20. Ivy JL, Miller W, Dover V, Goodyear LG, Sherman WM, Farrell S, Williams H. Endurance improved by ingestion of a glucose polymer supplement. Med Sci Sports Exerc 1983;15:466-471.

21. McArdle WD, Katch FI, Katch VL. Exercise physiology: Energy, nutrition, and human performance. 2nd ed. Philadelphia, PA: Lea and Febiger, 1986.

22. Cahill GF. Starvation in man. New Eng J Med 1970;282:668-675.

23. Consolazio CF, Johnson HL. Dietary carbohydrate and work capacity. Am J Clin Nutr 1972;25:85-90.

24. Kety SS. The general metabolism of the brain in vivo. In: Richter D, ed. Metabolism of the nervous system. New York: Pergamon Press, 1957: 221-237.

25. Costill DL, Sherman WM, Fink WJ, Maresh C, Witten M, Miller JM. The role of dietary carbohydrates in muscle glycogen resynthesis after strenuous running Am J Clin Nutr 1981;34:1831-1836.

26. Essen B. Intramuscular substrate utilization during prolonged exercise. Ann NY Acad Sci 1977;301:30-44.

27. Pernow B, Saltin B. Availability of substrates and capacity for prolonged heavy exercise in man. J Appl Physiol 1971;31:416-422.

28. Consolazio CF, Johnson RE, Pecora LJ. Physiological measurements of metabolic function in man. New York: Blakiston Division, McGraw-Hill Book Co., 1963.

29. Heigenhauser GJF, Sutton JR, Jones NL. Effect of glycogen depletion on the ventilatory response to exercise. J Appl Physiol 1983;54:470-474.

15. Krzentowski G, Jandrain B, Pirnay F, Mosora F, Lacroix M, Luyckx AS, Lefebvre PJ. Availability of glucose given orally during exercise. J Appl Physiol 1984;56:315-320.

16. Van Handel PJ, Fink WJ, Branam G, Costill DL. Fate of ^{14}C glucose ingested during prolonged exercise. Int J Sports Med 1980;1:127-131.

17. Hargreaves M, Costill DL, Coggan A, Fink WJ, Nishibata I. Effect of carbohydrate feedings on muscle glycogen utilization and exercise performance. Med Sci Sports Exerc 1984;16:219-222.

18. Costill DL, Miller JM. Nutrition for endurance sport: Carbohydrate and fluid balance. Int J Sports Med 1980;1:2-14.

19. Coyle EF, Hagberg JM, Hurley BF, Martin WH, Ehsani AA, Holloszy JO. Carbohydrate feeding during prolonged strenuous exercise can delay fatigue. J Appl Physiol 1983;55:230-235.

20. Ivy JL, Miller W, Dover V, Goodyear LG, Sherman WM, Farrell S, Williams H. Endurance improved by ingestion of a glucose polymer supplement. Med Sci Sports Exerc 1983;15:466-471.

21. McArdle WD, Katch FI, Katch VL. Exercise physiology: Energy, nutrition, and human performance. 2nd ed. Philadelphia, PA: Lea and Febiger, 1986.

22. Cahill GF. Starvation in man. New Eng J Med 1970;282:668-675.

23. Consolazio CF, Johnson HL. Dietary carbohydrate and work capacity. Am J Clin Nutr 1972;25:85-90.

24. Kety SS. The general metabolism of the brain in vivo. In: Richter D, ed. Metabolism of the nervous system. New York: Pergamon Press, 1957: 221-237.

25. Costill DL, Sherman WM, Fink WJ, Maresh C, Witten M, Miller JM. The role of dietary carbohydrates in muscle glycogen resynthesis after strenuous running Am J Clin Nutr 1981;34:1831-1836.

26. Essen B. Intramuscular substrate utilization during prolonged exercise. Ann NY Acad Sci 1977;301:30-44.

27. Pernow B, Saltin B. Availability of substrates and capacity for prolonged heavy exercise in man. J Appl Physiol 1971;31:416-422.

28. Consolazio CF, Johnson RE, Pecora LJ. Physiological measurements of metabolic function in man. New York: Blakiston Division, McGraw-Hill Book Co., 1963.

29. Heigenhauser GJF, Sutton JR, Jones NL. Effect of glycogen depletion on the ventilatory response to exercise. J Appl Physiol 1983;54:470-474.

30. Guyton, AC. Textbook of medical physiology. 6th ed. Philadelphia, PA: W.B. Saunders Co., 1981, 971-972.

31. Martin DW, Mayes PA, Rodwell VW. Harper's review of biochemistry. 19th ed. Los Altos, CA: Lange Medical Publications, 1983.

32. Bell GH, Emslie-Smith D, Paterson CR. Textbook of physiology and biochemistry. 9th ed. NY: Churchill Livingstone, 1976, pp 195-196.

33. Owen OE, Morgan AP, Kemp HG, Sullivan JM, Herrera MG, Cahill GF. Brain metabolism during fasting. J Clin Inves 1967;46:1589-1595.

34. Cahill GE, Aoki TT. Partial and total starvation. In: Assessment of energy metabolism in health and disease. Columbus, OH: Ross Laboratories, 1980:129-134.

Table 1. Appearance of urinary ketones during consumption of the control solution (no calories) during a 24-hour heat stress trial.

SUBJECT	TIME 9	12	15	18	21	24
1		X				
2		+		X		
3		++		+++/X		
4			X			
5			X			
6	X					
7	+	+	+/X			
8	X					
9		+	+ X			
10		+		++++/X		
12		+			+++/X	
13			+	+/X		

+=Trace
++=Small
+++=Moderate
++++=Large

X=Subject Dropped Out
+/X=Last reading when subject dropped out of test.

Table 2. Appearance of urinary ketones during consumption of the NBC Nutrient solution (calorie containing) during a 24-hour heat stress trial.

SUBJECT	TIME 9	12	15	18	21	24
1			X			
2						X
3		X				
4			X			
5			X			
6						X
7			X			
8			X			
9			+/X			
10			X			
12						+/X
13				X		

+=Trace
++=Small
+++=Moderate
++++=Large

X=Subject Dropped Out
+/X=Last reading when subject dropped out of test.

FIGURE LEGENDS

Figure 1. Blood albumin levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 2. Blood glucose levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 3. Blood lactate levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 4. Blood free fatty acid levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 5. Respiratory exchange ratio (RER) changes during two 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

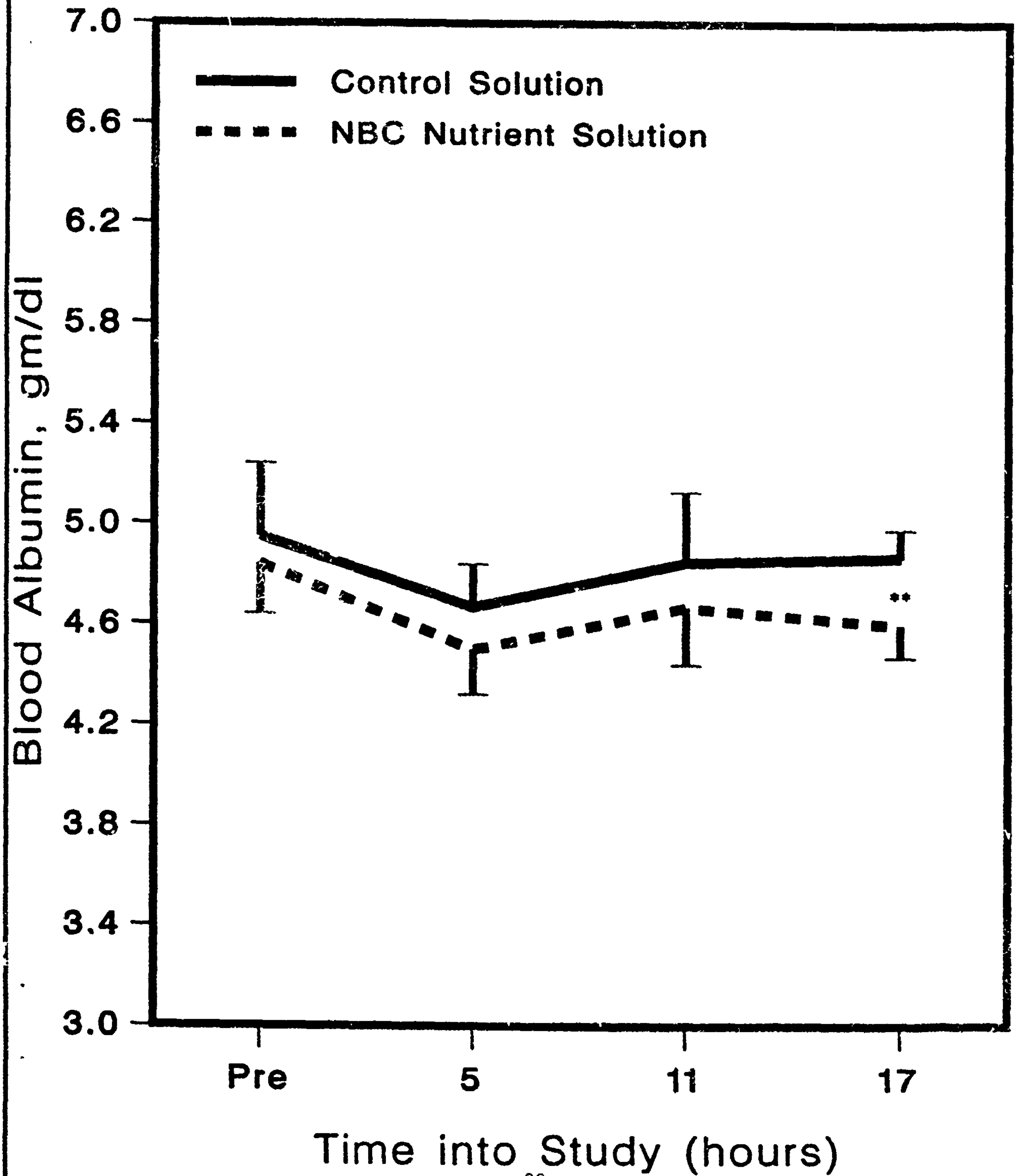
Figure 6. Blood urea nitrogen (BUN) levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 7. Blood creatinine levels during 24-hour heat stress trials of the NBC Nutrient solution and the control solution (n=11). Asterisks indicate _post hoc_ significance levels between the two solutions at that point in time (*=$p<0.05$, **=$p<0.01$).

Figure 1

NBC Nutrient Solution Study

Blood Albumin



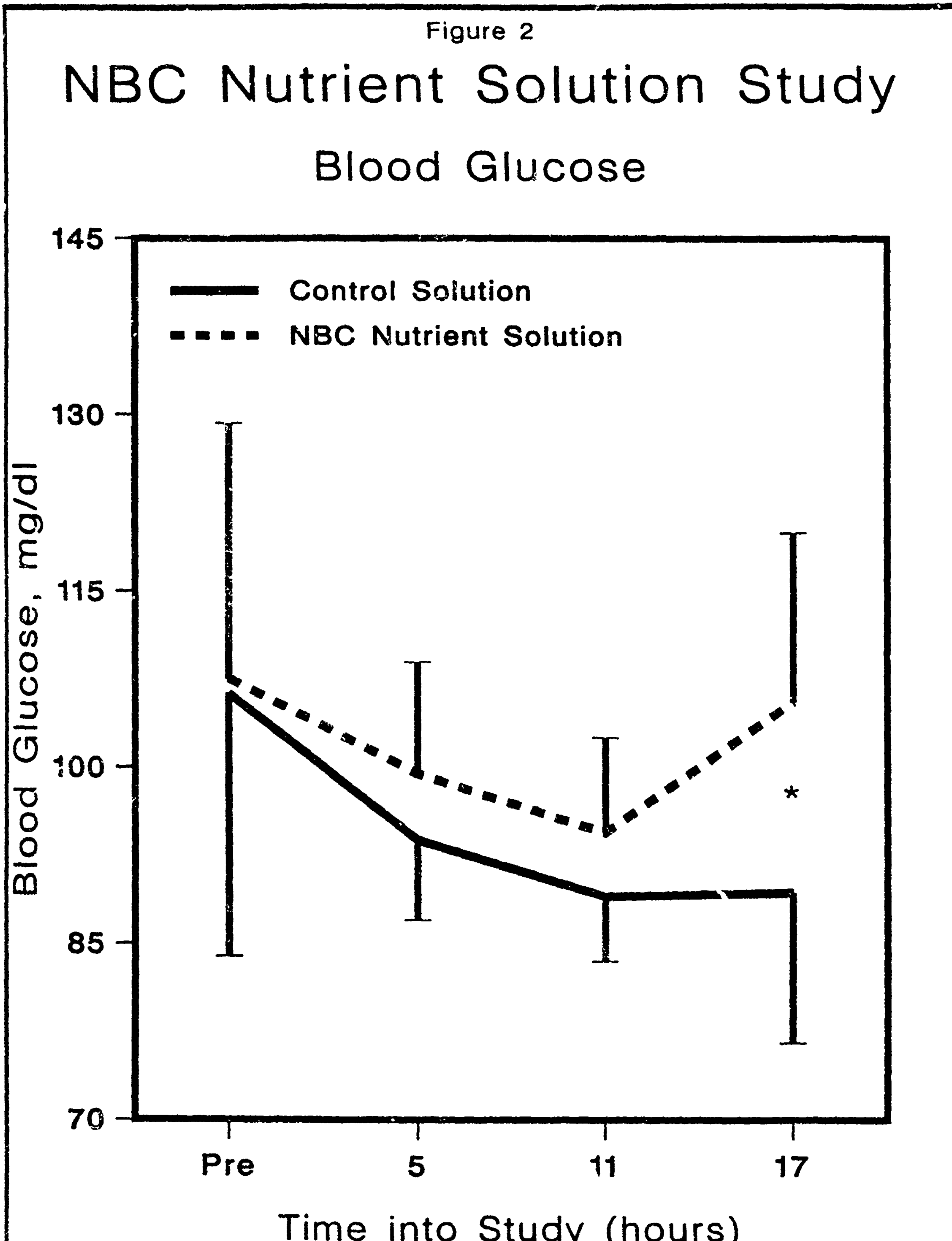


Figure 2
NBC Nutrient Solution Study
Blood Glucose
Control Solution
NBC Nutrient Solution
145
130
115
100
85
70
Blood Glucose, mg/dl
*
Pre
5
11
17
Time into Study (hours)

Figure 3

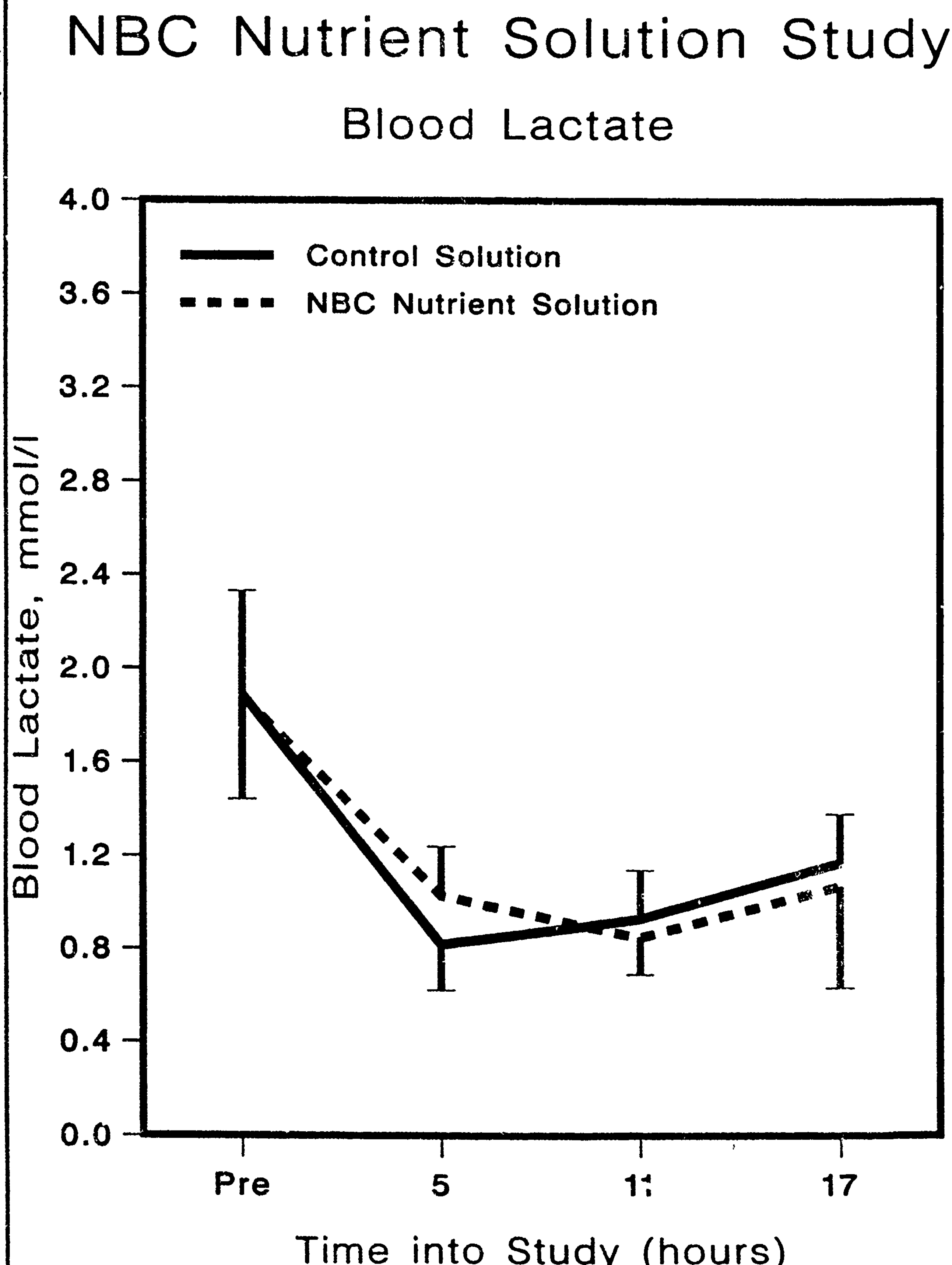
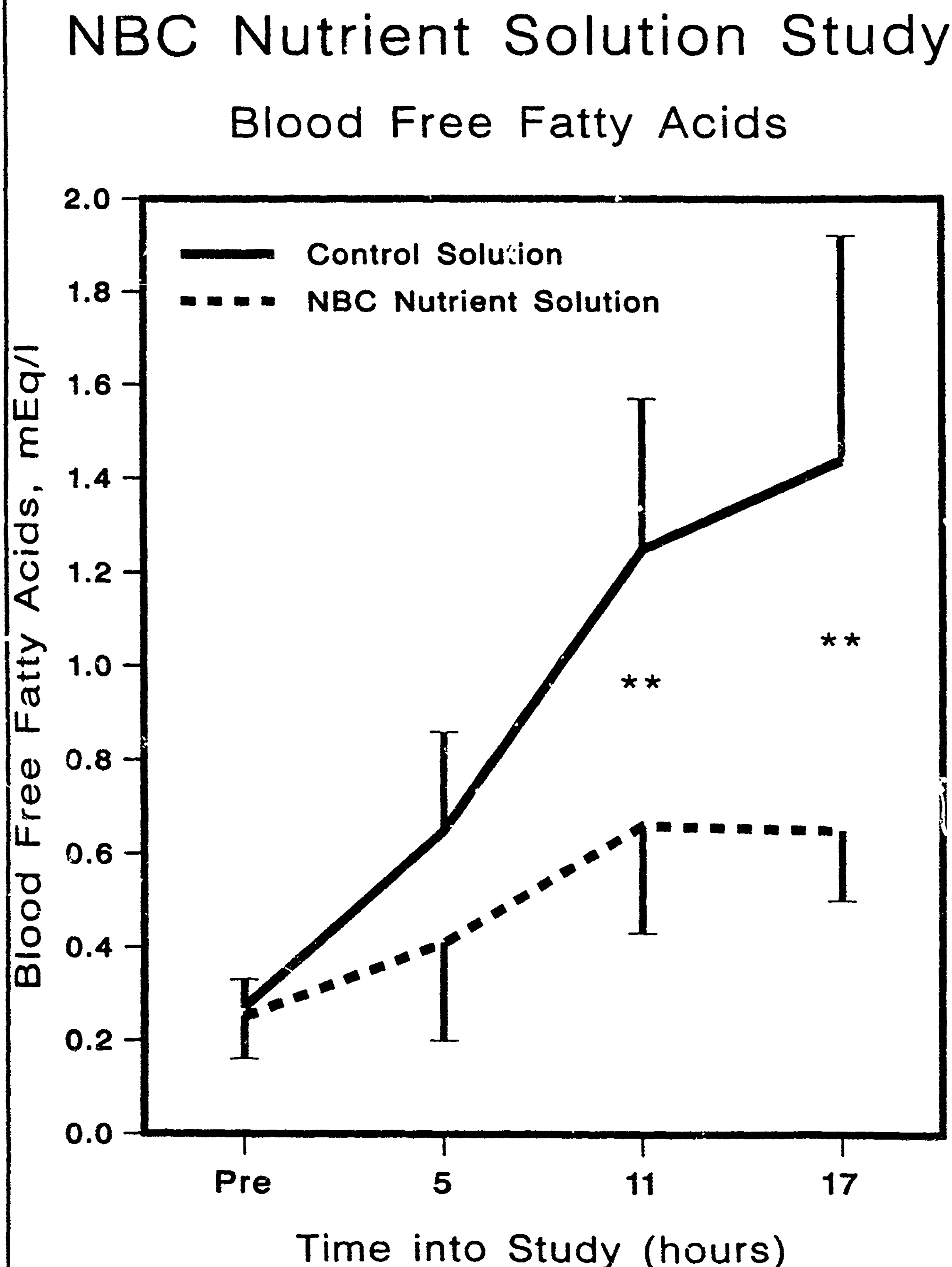

NBC Nutrient Solution Study
Blood Lactate
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
Blood Lactate, mmol/l
Control Solution
NBC Nutrient Solution
Pre
5
11
17
Time into Study (hours)

Figure 4



NBC Nutrient Solution Study
Blood Free Fatty Acids
Control Solution
NBC Nutrient Solution
Blood Free Fatty Acids, mEq/l
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
**
**
Pre
5
11
17
Time into Study (hours)

Figure 5

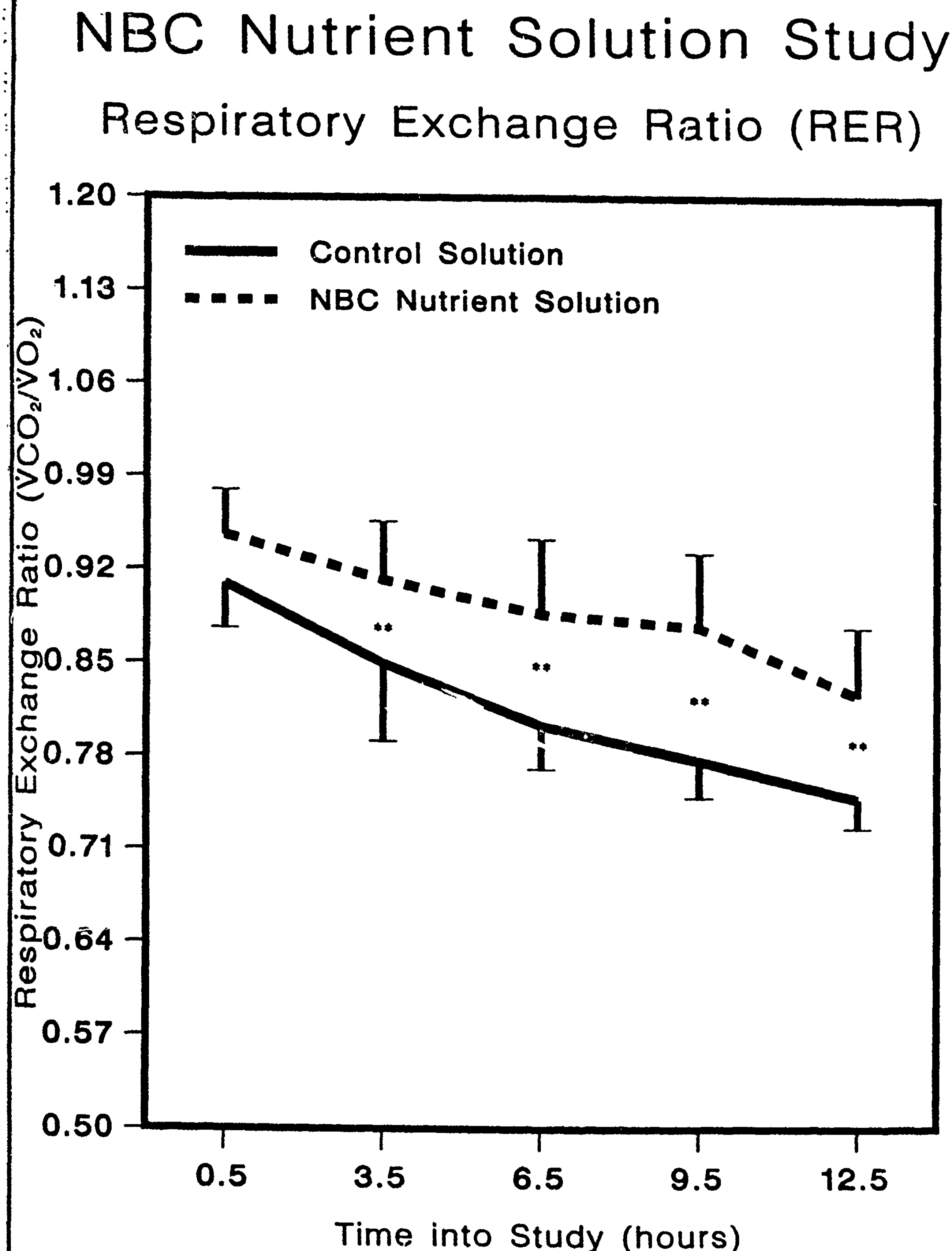

NBC Nutrient Solution Study
Respiratory Exchange Ratio (RER)
Control Solution
NBC Nutrient Solution
Respiratory Exchange Ratio (VCO₂/VO₂)
1.20
1.13
1.06
0.99
0.92
0.85
0.78
0.71
0.64
0.57
0.50
**
**
**
**
0.5
3.5
6.5
9.5
12.5
Time into Study (hours)

Figure 6

NBC Nutrient Solution Study

Blood Urea Nitrogen

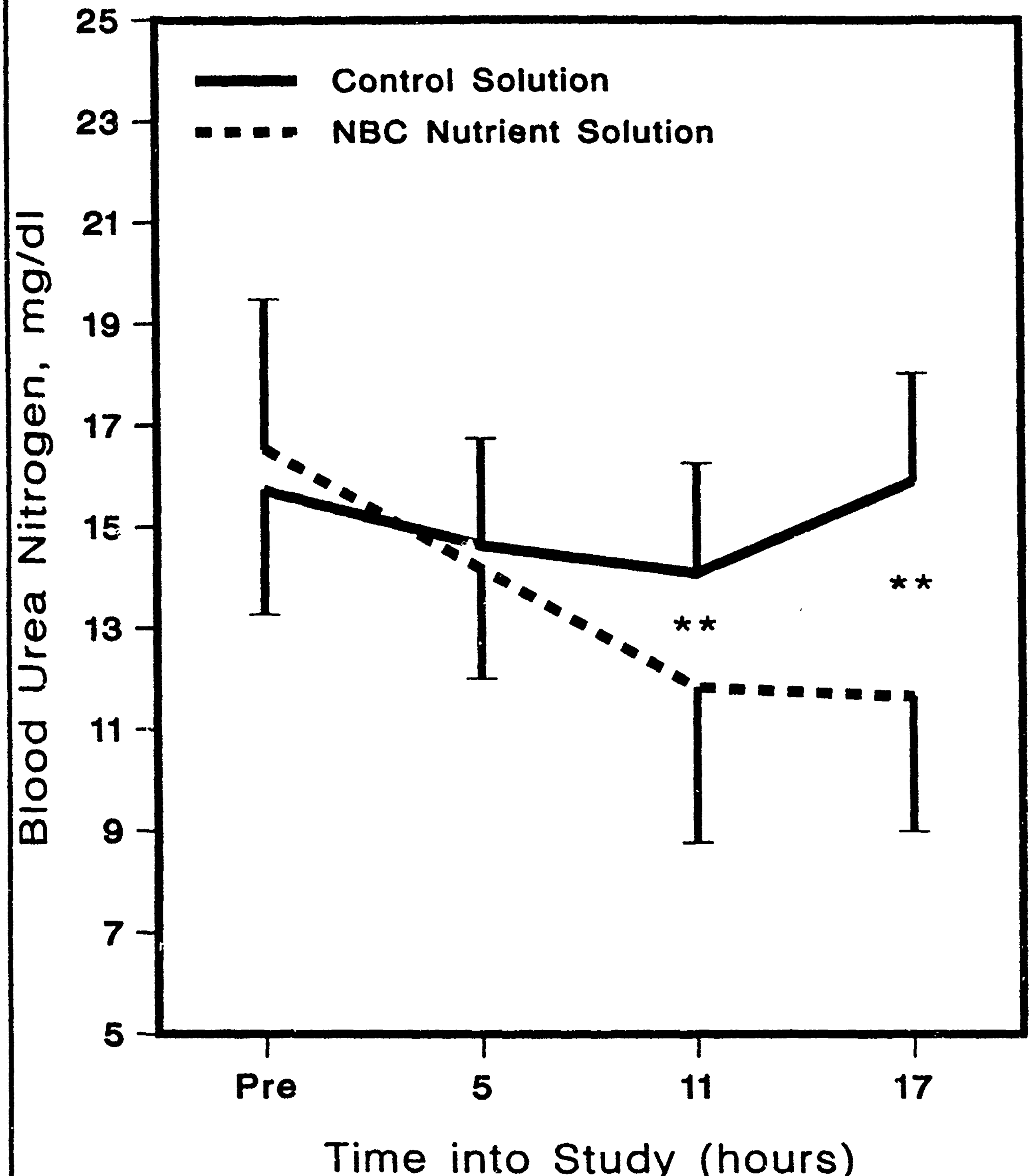
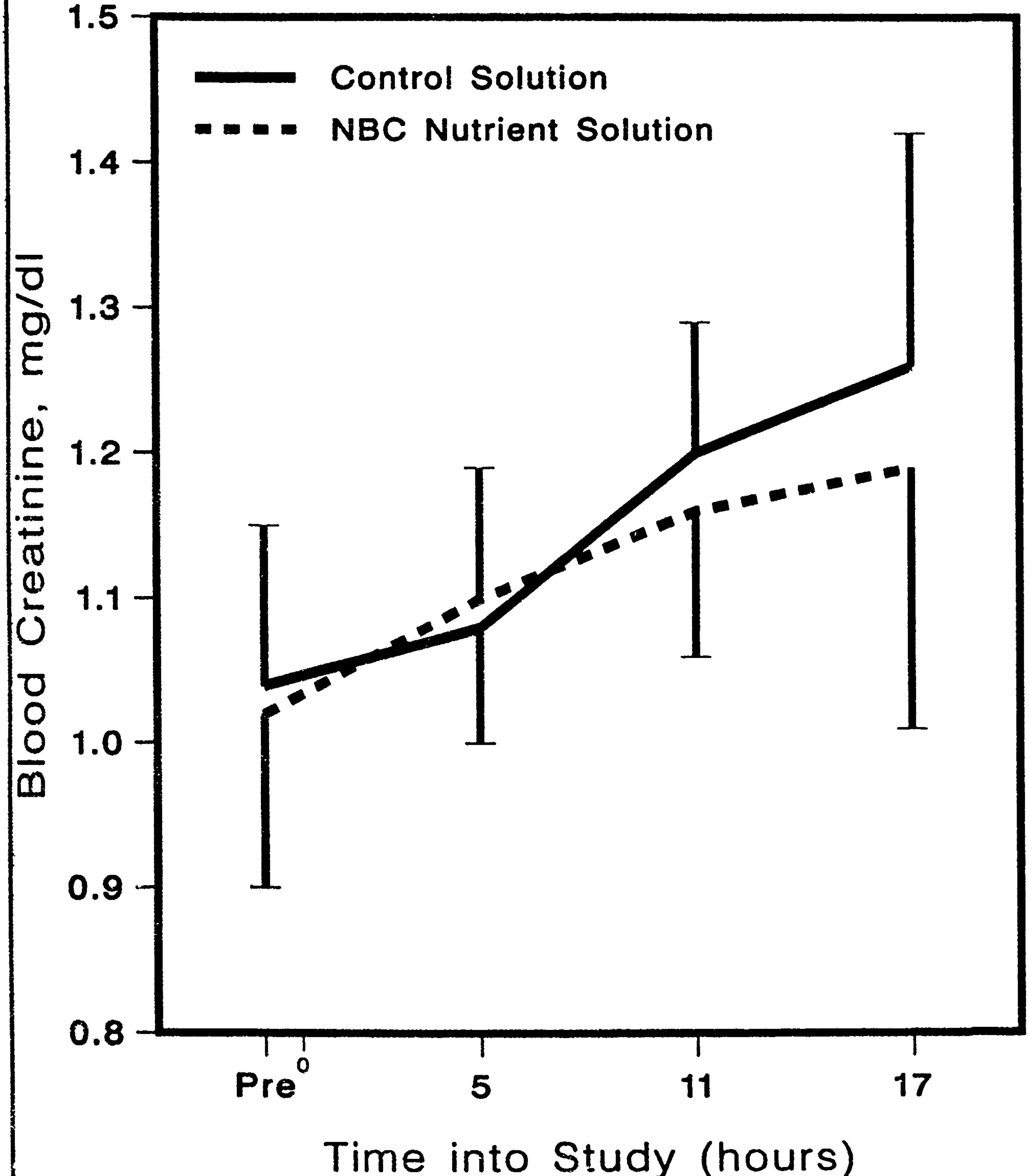


Figure 7

NBC Nutrient Solution Study

Blood Creatinine



PSYCHOLOGICAL ASSESSMENT

PSYCHOLOGICAL ASSESSMENT

COGNITIVE
AND
MOTOR PERFORMANCE TESTS

METHODS

Assessment Instruments

A variety of tasks were used to assess cognitive performance. Five paper and pencil tasks (Addition, Coding, Number Comparison, Map Compass, and Tower) were administered and three of these tasks (Addition, Coding, and Number Comparison) were also given on portable computers (Grid Compass II, Model 1131). All tasks were timed and sample items are shown in Figure 1. The Map Compass and Tower tasks were developed in our laboratory (1), while the remaining tasks were developed as part of the Navy's Performance Evaluation Tests for Environmental Research (PETER) program (2,3). All paper and pencil tasks were previously shown to be sensitive to a variety of environmental stessors (4-6); the computerized versions were used for the first time in this study. All paper and pencil tasks were generated on a laser copier (off-line from the computer) and each had 15 alternate forms. The computerized tasks were used along with the paper and pencil versions in an effort to validate them and they were developed so as to closely parallel their paper and pencil equivalents; all problems on these tasks were randomly generated.

The performance tasks used in this experiment require cognitive processes inherent in many real-world tasks. Addition requires summing three two-digit numbers. Coding requires writing the appropriate number for each "test" symbol from the information in the legend at the top of the page. This task is similar to manual procedures for encoding sensitive military communications. Numbe. Comparison requires indicating whether two numbers

are the same or different, which is similar to comparing part numbers, grid coordinates, or numbers on property inventories. Map Compass requires working with direction and degree relationships, conceptualization of changing spatial relationships, and the ability to calculate distances or new grid coordinates. Tower requires evaluating spatial problems with a series of learned algorithms and choosing an appropriate strategy, which is similar to the mental processes required for assembling mechanical components on a transmission or carburetor. Subjects decide if each problem is "possible" and "optimal", which requires logical reasoning and the ability to relate current information to prior experiences.

PROCEDURES

Pre-test sessions

Training was conducted with each set of subjects for five days. Subjects were trained twice daily, 60 minutes in the morning and 60 - 90 minutes in the afternoon in a Conditioning Room of the Climatic Chambers, NRD&EC. They were seated at tables and the temperature in the room ranged from 70 to 75^{0}F.

Extensive training and practice were given on all cognitive tasks. Performance feedback was also given to ensure that performance was stable and maximal by the second week of the study. Feedback was provided to the subjects until the afternoon of the fifth day of training; subjects were encouraged to respond as rapidly as possible while making some errors (<8%). Each task had been completed a minimum of twelve times before the subjects were evaluated experimentally. The Addition, Coding, and Number Comparison

tasks (paper and computer) were given for three minutes, the Map Compass task for four minutes, and the Tower task for six minutes.

Test sessions

The second and third week of the study were identical and were devoted to experimental testing. On Tuesday, baseline cognitive performance measurements were taken in the Tropic Wind Tunnel of the Climatic Chambers, NRD&EC. All tasks were given for the same durations as in the pre-test sessions except the Addition tasks (paper and computer) were given for five minutes. All subjects were always tested as a group and they were seated at tables during assessment.

On Thursday, during the 24-hour test session, subjects were always tested for 15 minutes, immediately after walking on the treadmill. Three 15 minute sessions were required to administer all the tasks; hence, every task was completed once each six hours. In the initial session (given 50, 410, 770, and 1130 minutes after the start of the 24-hour test) the Coding (computer), Coding (paper), and Map Compass tasks were given. In the second 15 minute test session (given 140, 500, 860, and 1220 minutes after the start of the 24-hour test) the Addition (computer) and Addition (paper) tasks were given. In the last 15 minute session (given 230, 590, 950, and 1310 minutes after the start of the 24-hour test) the Number Comparison (computer), Number Comparison (paper), and Tower tasks were given, in that order.

Statistical Analysis

A measure of cognitive performance was derived to reflect the combined effect of rate and accuracy changes, i.e. number of problems

correct/minute=(number of problems attempted - (number of problems wrong * weighting factor))/minute. Weighting factors appropriate for the number of response alternatives on each task were used.

Data from all tasks were submitted to two levels of statistical analysis. The first was a two-way repeated-measures analysis of variance (ANOVA). Data were first analyzed to determine whether there were overall differences across administrations, between conditions (subjects receiving the NBC Nutrient Solution and subjects receiving just the control solution), and whether there were any interactions between the two. Post hoc comparisons were then analyzed with Tukey's test to identify where these differences occurred. A significance level of $p \leq 0.05$ was chosen for all statistical tests.

Each performance task was analyzed so as to include the largest number of subjects for each condition since subjects terminated at different times during the test. For example, the tasks completed in the first 15 minute session were analyzed with data from 10 subjects, the tasks done in the second 15 minute session were analyzed with data from 8 subjects, and the tasks done in the third 15 minute session were analyzed with data from 4 subjects. Lost data for one subject on the third administration of Number Comparison (computer) were interpolated from his second and fourth administration values. Also, because no subject completed all the tasks under both conditions in the final six hours of the study, only data up to and including the third six hour session are presented.

RESULTS

During the five days' practice, task scores increased markedly. Final practice values were 1.5 - 2.2 times greater than initial day training values. Correlations between day 5 training values and pre-test baseline values for all tasks ranged from 0.61 to 0.95, suggesting that subjects were well practiced and performance was stable before experimental exposure.

Shown in Table 1 are the means and standard deviations for each cognitive task (number correct/minute) by solution condition and administration. Also shown is the number of subjects (N) for each cognitive task. There were no significant overall solution effects for any of the cognitive tasks. Three tasks showed a significant administration effect. Specifically, the Coding (paper) task is shown in Figure 2, the Number Comparison (computer) task in Figure 3, and the Map Compass task in Figure 4. However, only Number Comparison (computer) showed any *post hoc* differences. The mean performance value for the third administration of the control solution was significantly less than the first and second administration values. *Post hoc* comparisons also revealed that the mean value for the third administration of Addition (paper) on the control solution was significantly less than the pre-test value for the control solution (Figure 5).

DISCUSSION

These results indicate that there were no main effects for the solution; however, the final performance value for the control solution was less than

that for the NBC Nutrient Solution on seven of the nine cognitive tasks (third administration). These differences were not significant. It was not until the third administration on any of the cognitive tasks that values decreased from the pre-test scores. However, at this time (15-16 hours after the start of the test) only eight and four subjects remained in both conditions. Therefore, since cognitive performance did not decrease until the third administration - a time when few subjects remained in the study - it is difficult to evaluate whether the NBC Nutrient Solution had a beneficial effect on performance.

Even though there were no main effects due to the solution, there was an administration effect on three of the cognitive tasks. Also, on the Addition (paper) task, the mean value for the last administration for the control solution was significantly lower than the pre-test value. These results indicate that the cognitive performance tasks administered were sensitive to increased durations in the study.

The test conditions in this study may not have been appropriate to evaluate the NBC Nutrient Solution. It was not until 15-16 hours after the start of the test that the difference between the two solutions (control solution performance decreased) started to appear. However, no subject endured another six hour test battery on both the NBC Nutrient Solution and the control solution. Therefore, it cannot be said whether the solution did actually sustain scores over the control solution alone. Another study in which the subjects endured longer or were more stressed earlier would be needed to determine the value of the NBC Nutrient Solution for sustaining cognitive performance.

CONCLUSIONS

1. There were no significant differences between solutions and over time on cognitive and motor performance tests under the conditions of this study.
2. Performance was not enhanced by the NBC Nutrient Solution on any of the cognitive tasks.
3. The results of the present study should be interpreted cautiously because the test conditions could have resulted in underestimation of the solution effect.

REFERENCES

1. Banderet LE, Benson KP, MacDougall DM, Kennedy RS, Smith M. Development of cognitive tests for repeated performance assessment. Proceedings of the 26th annual meeting, Military Testing Association. Munich, Federal Republic of Germany 1984:375-380.

2. Carter RC, Sbisa H. Human performance tests for repeated measurements: Alternate forms of eight tests by computer. Report NBDL8213003 Naval Biodynamics Laboratory, New Orleans, LA. 1982.

3. Bittner AC Jr, Carter RC, Kennedy RS, Harbeson MM, Krause M. Performance evaluation tests for environmental research: Evaluation of 112 measures. Report NBDL84R006 or NTIS AD152317 Naval Biodynamics Laboratory, New Orleans, LA. 1984.

4. Jobe JB, Banderet LE. Cognitive testing in military performance research. Proceedings, Workshop on Cognitive Testing Methodology. Washington, DC: National Academy Press 1986:181-193.

5. Banderet LE, MacDougall DM, Roberts DE, Tappan D, Jacey M, Gray P. Effects of dehydration or cold exposure and restricted fluid intake on cognitive performance. Proceedings, Workshop on Predicting Decrements in Military Performance Due to Inadequate Nutrition. Washington, DC: National Academy Press 1986:69-79.

6. Banderet LE, Shukitt BL, Crohn EA, Burse RL, Roberts DE, Cymerman A. Effects of various environmental stressors on cognitive performance. Proceedings of the 28th annual meeting, Military Testing Association. Mystic, CN. 1986 (in press).

TABLE 1. COGNITIVE TASK PERFORMANCE FOR THE NBC NUTRIENT SOLUTION
Mean number correct/minute and standard deviations for each cognitive task by condition and administration

	N	CONTROL	NBC SOLUTION
ADDITION (Computer)	8		
Pre-test		8.50 ± 3.29	8.30 ± 3.08
Admin 1		8.25 ± 2.86	7.90 ± 2.62
Admin 2		7.93 ± 3.10	8.35 ± 2.88
Admin 3		7.85 ± 3.26	7.78 ± 2.86
ADDITION (Paper)	8		
Pre-test		11.33 ± 5.75	11.23 ± 4.94
Admin 1		11.10 ± 4.96	11.13 ± 4.73
Admin 2		10.70 ± 4.88	11.28 ± 4.80
Admin 3		9.85 ± 5.30	10.53 ± 4.84
CODING (Computer)	10		
Pre-test		36.70 ± 7.38	36.37 ± 5.97
Admin 1		36.70 ± 6.43	36.30 ± 7.51
Admin 2		37.43 ± 7.75	35.70 ± 7.07
Admin 3		33.57 ± 9.31	37.60 ± 7.19
CODING (Paper)	10		
Pre-test		39.83 ± 5.06	39.37 ± 6.46
Admin 1		40.10 ± 5.25	41.80 ± 5.92
Admin 2		40.27 ± 4.63	42.17 ± 5.50
Admin 3		36.60 ± 6.35	38.73 ± 6.10
NUMBER COMPARISON (Computer)	4		
Pre-test		25.08 ± 5.33	27.00 ± 3.54
Admin 1		28.33 ± 3.96	28.33 ± 2.79
Admin 2		26.75 ± 9.41	28.25 ± 4.33
Admin 3		20.33 ± 4.63	24.50 ± 4.24
NUMBER COMPARISON (Paper)	4		
Pre-test		23.67 ± 5.83	21.33 ± 4.08
Admin 1		23.25 ± 5.46	23.58 ± 3.70
Admin 2		22.58 ± 5.99	24.67 ± 6.48
Admin 3		21.67 ± 6.93	25.67 ± 6.38

SOLUTION	N	CONTROL	NBC
MAP COMPASS	10		
Pre-test		5.00 ± 1.81	5.00 ± 2.15
Admin 1		4.86 ± 2.00	4.72 ± 2.03
Admin 2		5.40 ± 2.15	5.32 ± 2.01
Admin 3		4.84 ± 1.96	5.28 ± 2.18
TOWER (Possible)	4		
Pre-test		10.75 ± 1.26	9.88 ± 0.98
Admin 1		10.17 ± 0.91	9.33 ± 1.31
Admin 2		10.13 ± 2.77	9.63 ± 1.07
Admin 3		8.71 ± 1.72	9.38 ± 1.96
TOWER (Optimal)	4		
Pre-test		4.08 ± 1.29	3.54 ± 1.21
Admin 1		3.58 ± 1.57	3.46 ± 1.02
Admin 2		4.13 ± 1.54	3.37 ± 1.18
Admin 3		3.50 ± 1.08	3.33 ± 1.58

FIGURE 1

SAMPLE ITEMS FOR EACH COGNITIVE TASK

CODING

NUMBER: 1 2 3 4 5 6 7 8
SYMBOL: O = U – L X > /

L O > = > L / O X – /
( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( )

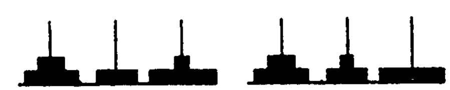
NUMBER COMPARISON

845793858 __ 845793858
50237 __ 20237
976 __ 976
0623385 __ 0623325
239055610 __ 233055610

ADDITION

71	20	27	53	20
19	51	83	33	35
76	40	47	67	11
___	___	___	___	___

TOWER OF HANOI



POSSIBLE? YES__ NO__
OPTIMAL? YES__ NO__

MAP COMPASS

PVT JENSEN TRAVELS ON AN AZIMUTH OF 4. WHAT DIRECTION IS HE TRAVELING?
__SE __NW __S __N

A COMPANY IS LOCATED AT GRID COORDINATE 112801. ORDERS COME FOR THE COMPANY TO MOVE SOUTH 1800 METERS. WHAT IS THE GRID COORDINATE OF THE NEW LOCATION? __094801 __130801 __112819 __112783

FIGURE 2. CODING (PAPER)

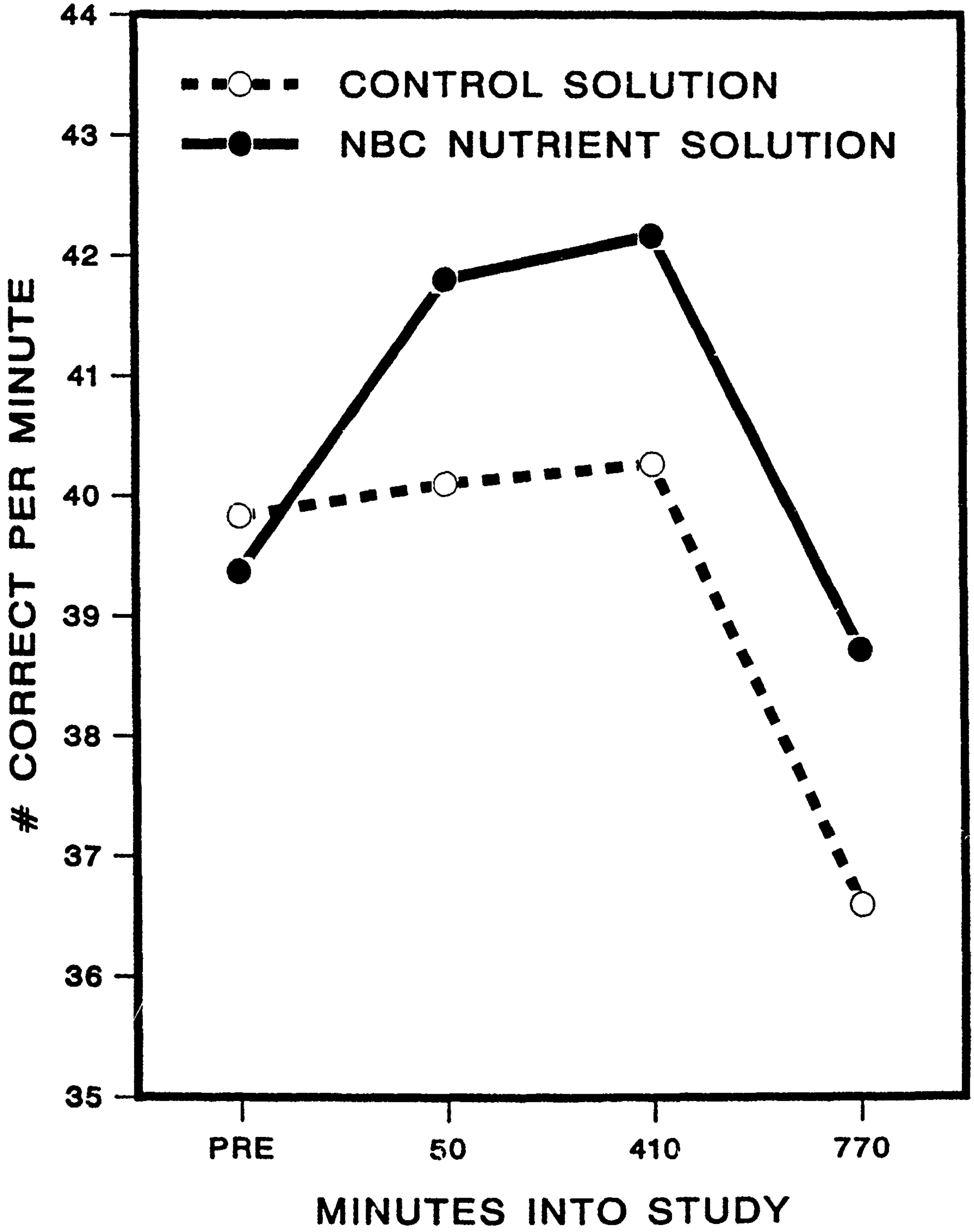


FIGURE 3. NUMBER COMPARISON (COMPUTER)

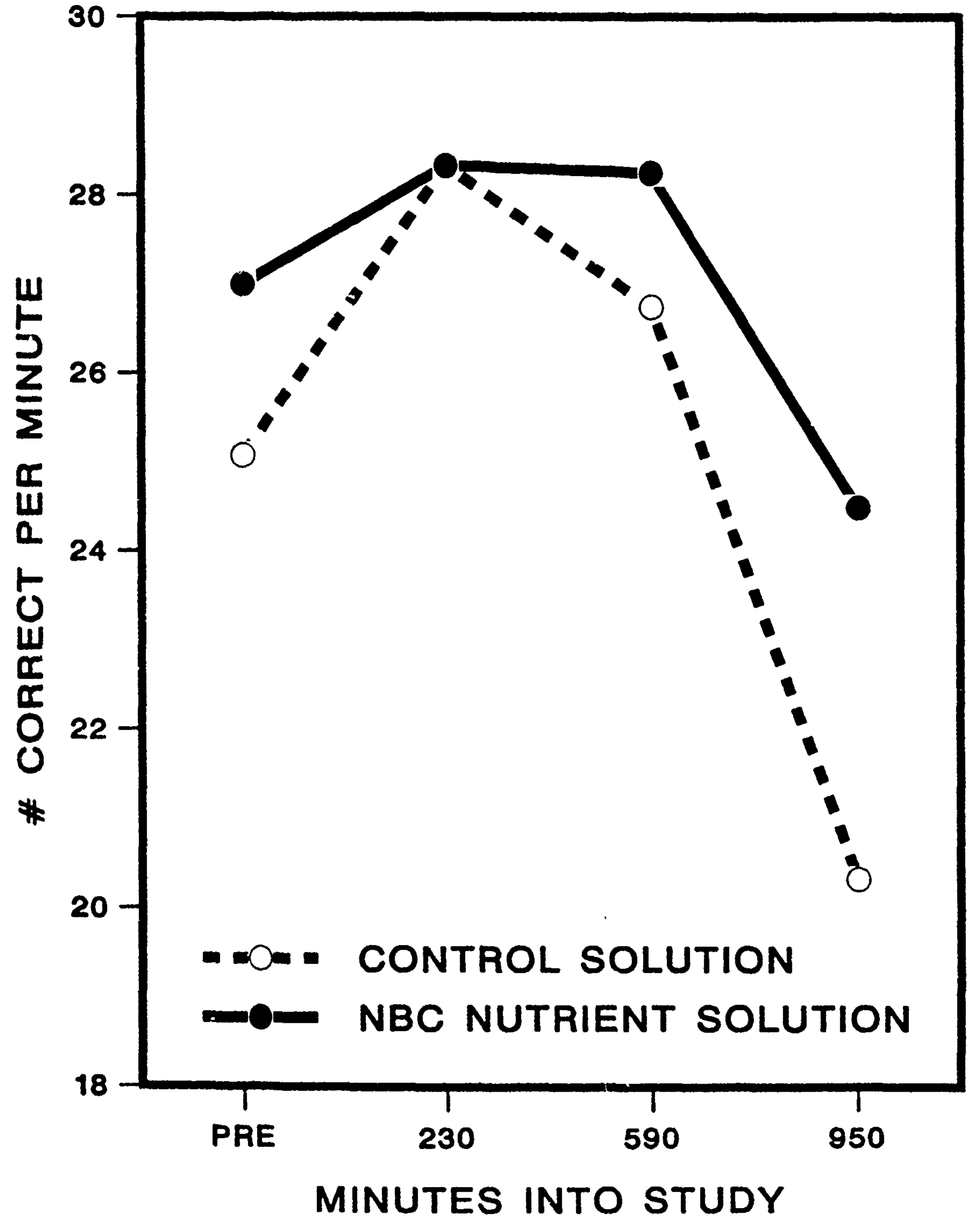


FIGURE 4. MAP COMPASS

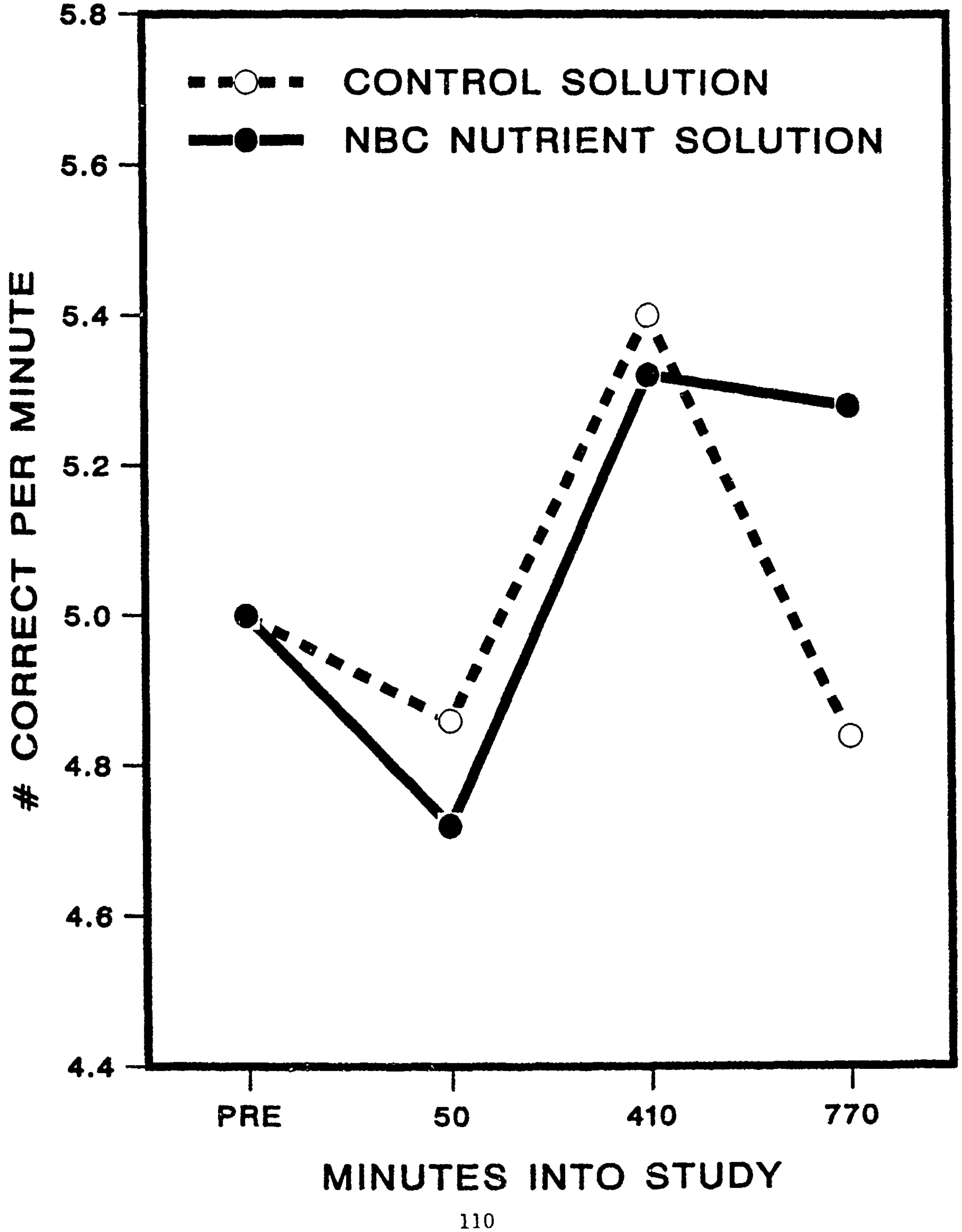
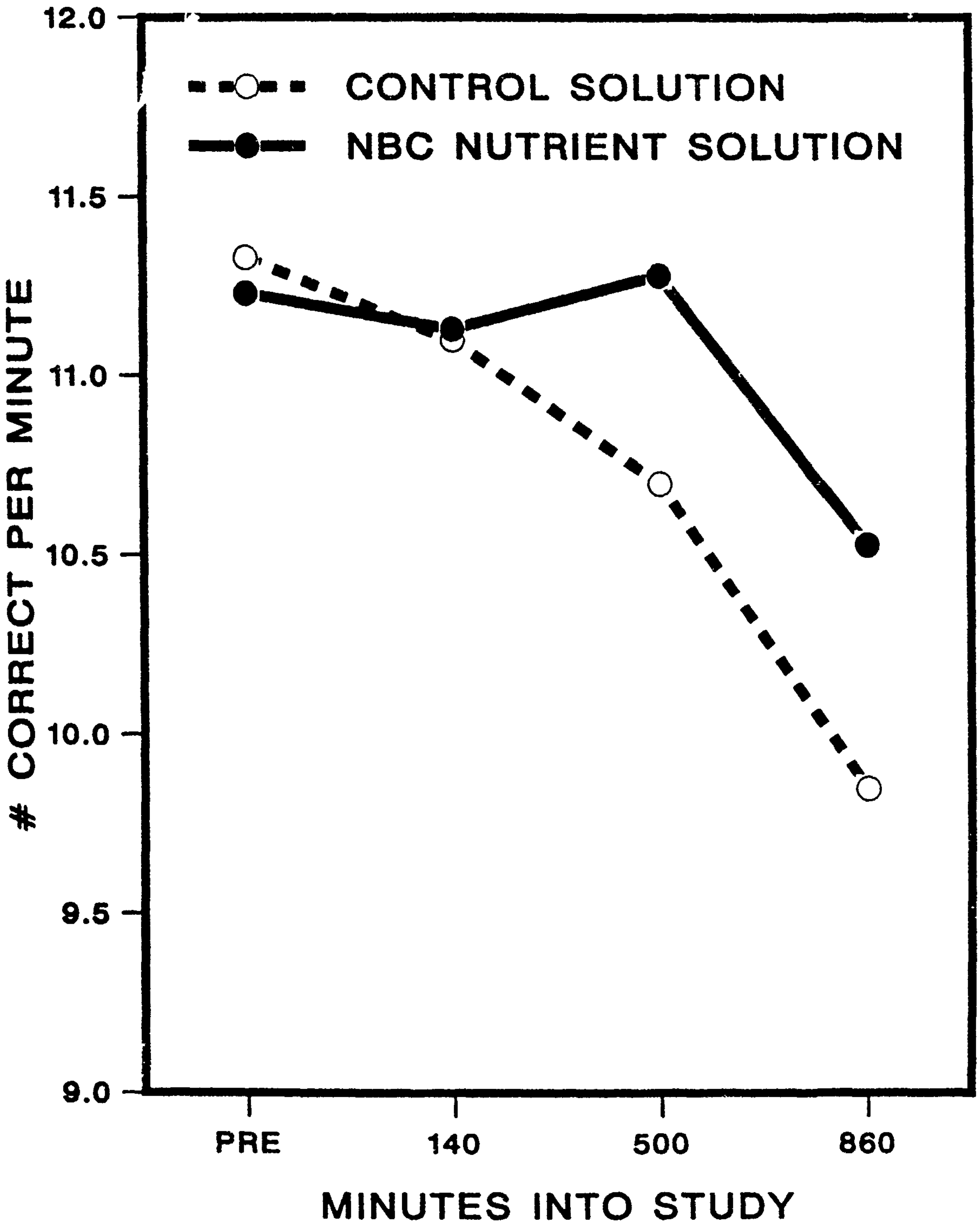


FIGURE 5. ADDITION (PAPER)



PSYCHOLOGICAL ASSESSMENT

VIGILANCE MEASURES

METHODS

Vigilance Measure

Vigilance was measured using a program developed in our laboratory which ran on pocket computers (Sharp PC-1500A). The dimensions of the computers are 195mm(W) x 25.5mm(H) x 86mm(D) and they weigh 375g each. Each computer has a 26 digit liquid crystal display of 7 x 156 dots.

During the vigilance task the computer displayed a sequence of single digits. Each digit was displayed for 200ms with an inter-digit interval of 350ms. Subjects were required to detect a sequence of three digits in which the first was an odd, the second was an even, and the third was an odd which was different from the first. Thus, 3-4-5 was a target. Sequences which included odd-even-odd, where the two odds were the same (e.g. 3-4-3), were distractors. When a target was displayed, the subject was to respond by pressing the space bar on the keyboard. Whenever the space bar was pressed during the test, an asterisk (*) appeared on the display. Test sessions lasted about 20 min and included a random number of targets and distractors with an average of 20 of each per session. Because a different number of possible target hits and distractor hits for each session were created during the randomization procedure, subjects' scores were expressed as percentages. Sessions were analyzed on four measures: 1) % target hits, 2) % distractor hits, 3) % bad hits and 4) sensitivity score. Sensitivity scores were calculated using a nonparametric sensitivity measure which is an estimate of area under the Receiver Operating Characteristic (ROC) curve (1,2).

During three days of the acclimation phase of the study, the subjects performed the vigilance task once in the morning and once in the afternoon. This assured that the subjects were very familiar with the task and provided baseline data.

RESULTS

Mean baseline scores on each of the vigilance measures were calculated for each subject using the last four of the six practice sessions during the acclimation phase. For the purpose of analyzing the data, % target hits, % distractor hits, % bad hits, and sensitivity scores, which were obtained during the test phase, were expressed as percents of their baseline counterparts. Analyses of variance were performed on the percent change from the baseline. Too few subjects completed the full 24 hours of the test phase to permit the inclusion of all four of the planned test trials in the analysis. Thus, only the first two vigilance trials in the test phase were included.

Figures 1-4 show the means for the four measures of performance on the vigilance task. The analysis of target hits revealed no significant effects of the NBC Nutrient solution ($\underline{F}(1, 8) < 0.01$, $\underline{p}=0.99$). An inspection of the data reveals that this result is largely due to the great amount of variability in the scores for this measure. Target hit performance did not degrade significantly over time during the test ($\underline{F}(1, 8)=0.95$, $\underline{p}=0.36$). It will be recalled that this analysis included only the first two vigilance sessions during the test phase (5.5 and 11.5 hours into the study), because

too few subjects participated in the latter sessions. However, Figure 1 reveals an apparent trend toward a degradation of performance in the last session of vigilance testing.

The analysis of the data from bad hits also showed no significant effects of either the NBC Nutrient solution ($\underline{F}(1, 8)=0.71$, $\underline{p}=0.42$) or time during the test phase ($\underline{F}(1, 8)=0.07$, $\underline{p}=0.80$). As with target hits there is a suggestion of a trend toward fewer bad hits over time during the test (Figure 2). This trend toward decreased hits, or possible attempts of any kind, was also present in the analysis of distractor hits. The number of distractor hits was not significantly affected by either the NBC Nutrient solution ($\underline{F}(1, 8)=0.07$, $\underline{p}=0.79$) or time during the test phase ($\underline{F}(1, 8)=0.86$, $\underline{p}=0.38$, see Figure 3).

Sensitivity scores, which provide an estimate of unbiased sensitivity to responding to the target, showed no significant effect of either the NBC Nutrient solution ($\underline{F}(1, 8)=0.31$, $\underline{p}=0.60$) or time during the test phase ($\underline{F}(1, 8)=0.31$, $\underline{p}=0.60$, see Figure 4).

Due to the apparent trend of decreasing % target hits, % distractor hits, and % bad hits, an additional analysis was performed using the total number of responses per trial as a measure of vigilance performance. It was found that type of solution ($\underline{F}(1, 8)=0.22$, $\underline{p}=0.65$) and time during the test phase ($\underline{F}(1, 8)=0.87$, $\underline{p}=0.38$) had no effect on the total number of responses per trial.

Whereas no significant values were found when scores were grouped according to type of solution and time during the test phase, significant results were obtained when scores were grouped according to test day order

and time during the test phase. Subjects' performance was affected by test day order regardless of what type of solution they consumed. Separate ANOVAs were computed for each of the four measures of vigilance. As with the previous analyses, scores were expressed as percent changes from their baseline counterparts.

It was found that test day order had an effect on target hit performance ($\underline{F}(1, 8)=8.63$, $\underline{p}<0.02$), with subjects scoring fewer target hits on their second test day. Time during the test phase had no effect on target hit scores ($\underline{F}(1, 8)=0.95$, $\underline{p}=0.359$). Subjects' scores for bad hits were not affected by test day order ($\underline{F}(1, 8)=0.53$, $\underline{p}=0.49$) or by time during the test phase ($\underline{F}(1, 8)=0.07$, $\underline{p}=0.80$). Subjects scored somewhat fewer distractor hits on their second test day ($\underline{F}(1, 8)=4.64$, $\underline{p}=0.06$). Time during the test phase had no effect on distractor hit scores ($\underline{F}(1, 8)=0.86$, $\underline{p}=0.38$). Sensitivity scores demonstrated an effect of test day order ($\underline{F}(1, 8)=5.82$, $\underline{p}<0.05$), with subjects' performance decreasing on the second test day. Time during the test phase had no effect on sensitivity scores ($\underline{F}(1, 8)=0.31$, $\underline{p}=0.59$).

DISCUSSION

Statistical analyses of the two trials revealed no significant effects of either the NBC Nutrient solution or time for the four measures of vigilance that were obtained. The apparent lack of effect of type of solution consumed or time during the test phase may be explained in two ways. First, the large variability in the performance of the subjects on the vigilance task contributed substantially to the difficulty in revealing any effects that

might exist for the measures of vigilance. Figures 1 to 3 show a consistent trend of fewer responses as time passed during the test phase. A combined score which reflects the subjects' total number of responses (target hits + bad hits + distractor hits) during a trial was analyzed, with no differences found among the trials. In future studies of this sort, refinements of the task itself might reduce the amount of variability. We would also want to include more trials and, when possible, more subjects in subsequent studies.

The second possible explanation for the absence of significant effects is that the NBC Nutrient solution had no effect on vigilance. Indeed, there is no evidence to indicate that NBC Nutrient solutions affect vigilance performance under conditions similar to those examined in this study. It was anticipated that the combined effects of fatigue, hunger, etc. would produce a degradation of vigilance performance, and that the NBC Nutrient solution would have a positive effect on that degradation. However, this did not happen. Thus, while there is a hint that vigilance did decrease over time in the test, it is clear that the NBC Nutrient solution did not improve this degraded performance.

Due to the lack of effect of solution and time during the test phase, another set of analyses were performed by grouping the subjects' scores in regard to test day order and time during the test phase. Target hits, distractor hits, and sensitivity scores were affected by test day order with subjects responding less on their second test day regardless of what solution they consumed. Perhaps this effect of test day order contributed to the variability of scores resulting in no differences between the NBC Nutrient solution trial and the control solution trial. In the future, it is

recommended that subjects be given a recovery period that is longer than the one-week period given in the present study.

CONCLUSIONS

1. Compared to the control solution, the NBC Nutrient solution did not affect performance on the computer vigilance task. Measures including % target hits, % bad hits, % distractor hits, and sensitivity scores were analyzed and were not statistically different.

2. Time during the test phase also had no effect on the four measures of vigilance. Subjects who were included in the analysis demonstrated no degradation of performance over time.

3. Test day order was found to affect performance on three of the four measures of the vigilance task. Subjects responded to fewer targets and distractors, and scored lower on the sensitivity measure on their second test day regardless of what solution they consumed.

REFERENCES

1. Brown Grier J. Nonparametric indexes for sensitivity and bias: Computing formulas. Psychological Bulletin 1971;75:424-429.

2. Pollack I, Norman DA. A nonparametric analysis of recognition experiments. Psychonomic Science 1964;1:125-126.

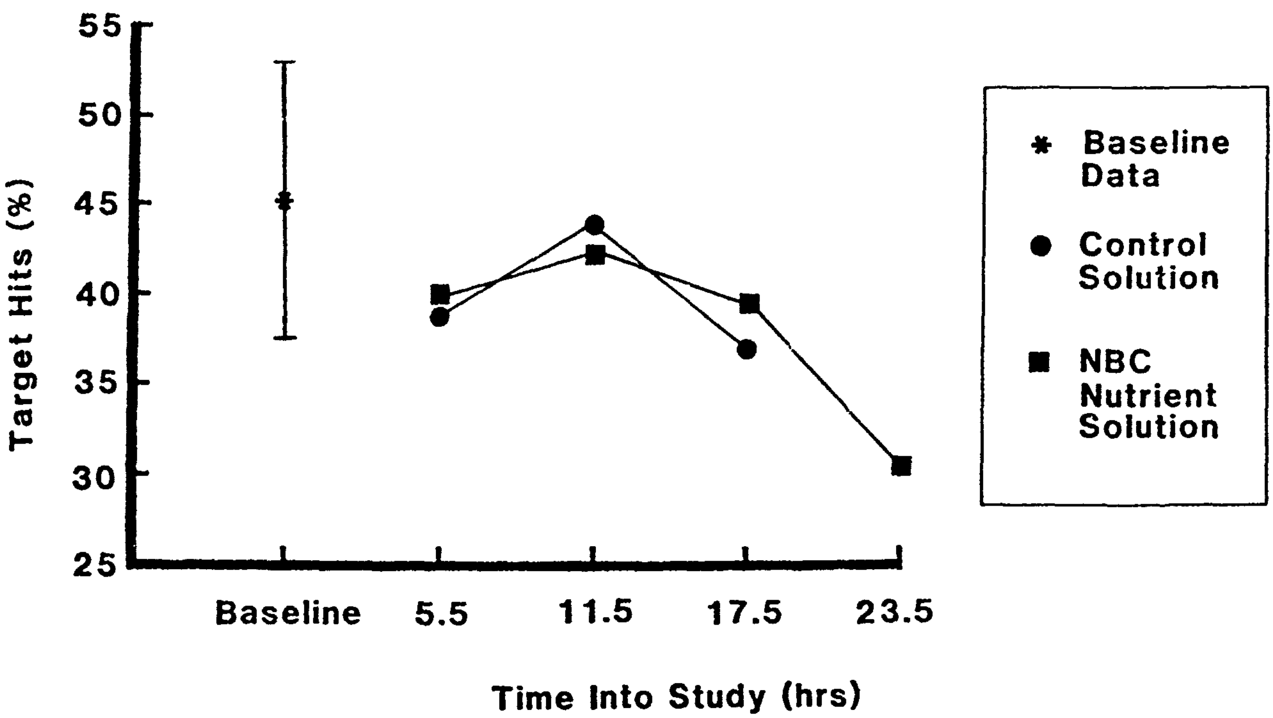


Figure 1. Percent target hits as a function of time. Plotted are means, and the standard error for baseline.

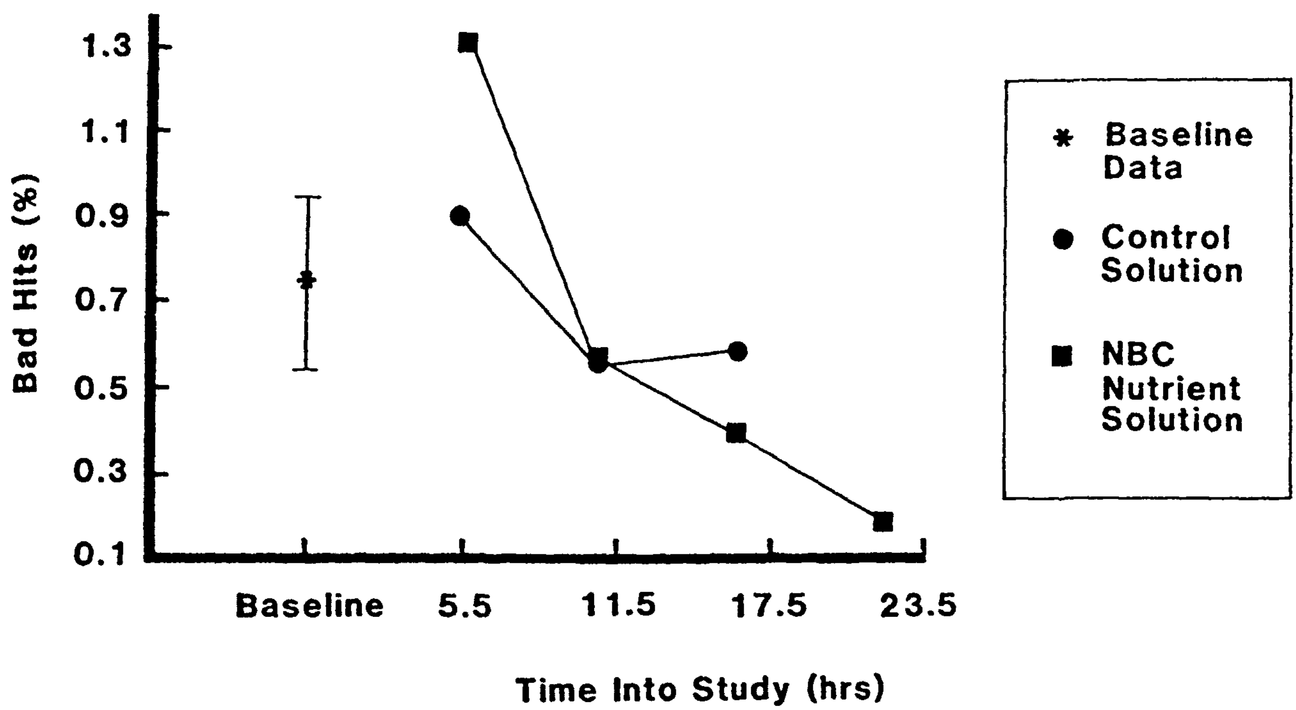


Figure 2. Percent bad hits as a function of time. Plotted are means, and the standard error for baseline.

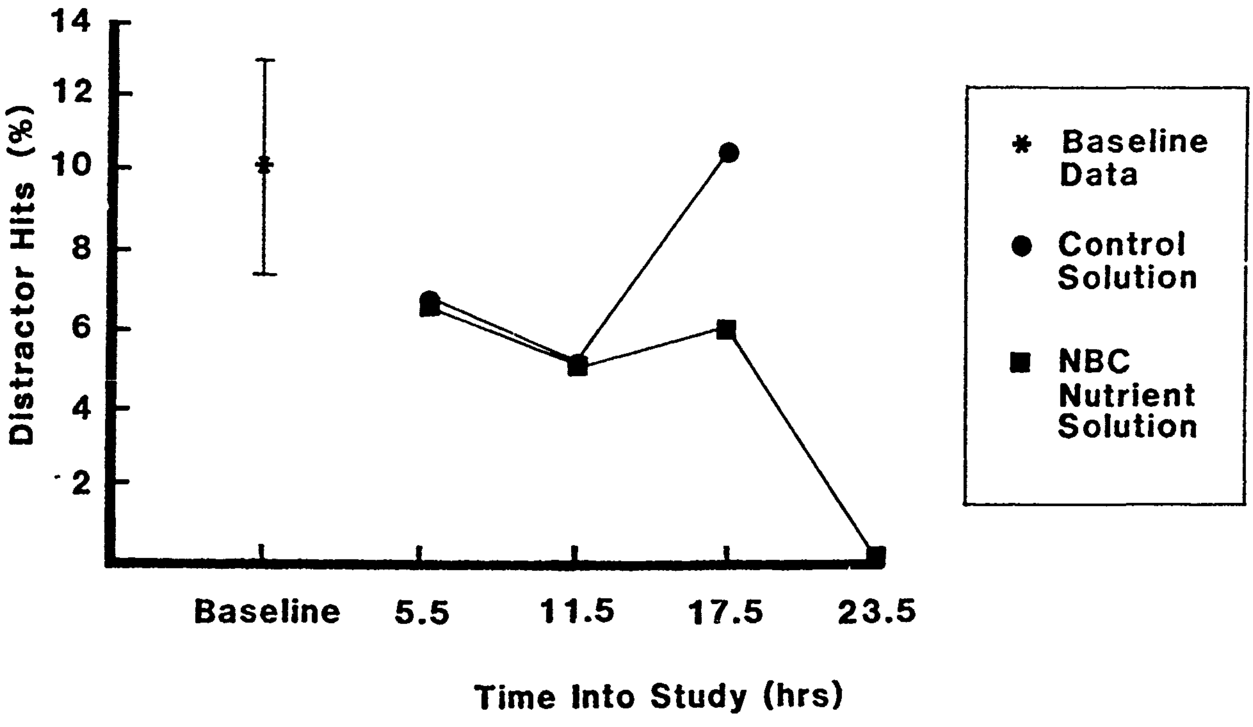


Figure 3. Percent distractor hits as a function of time. Plotted are means, and the standard error baseline.

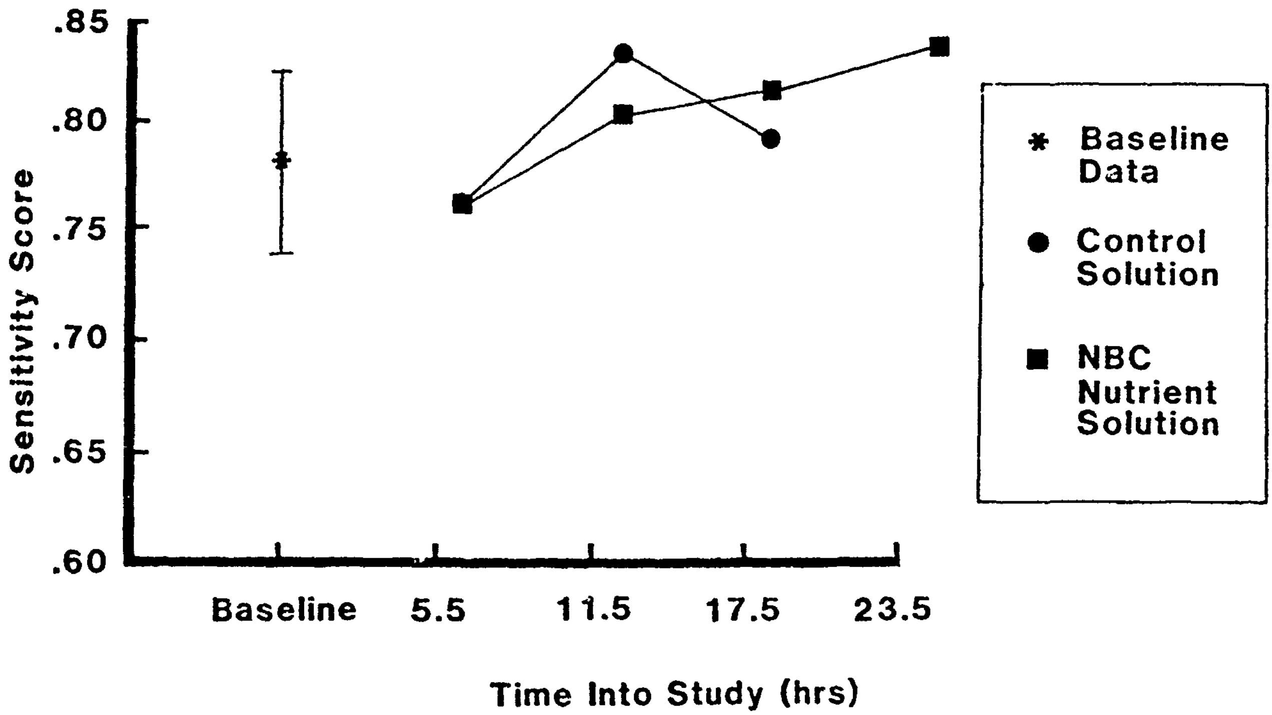


Figure 4. Sensitivity scores as a function of time. Plotted are means, and the standard error for baseline.

PSYCHOLOGICAL ASSESSMENT

SELF-REPORTED SYMPTOMS AND MOOD STATES

METHODS

Test Materials and Apparatus

Two broad-based questionnaires were administered for a comprehensive assessment of test effects. (1) Environmental Symptoms Questionnaire (ESQ) [1]. Sixty-eight items were presented. Most items described physical rather than psychological symptoms. The intensity of each item was rated on a six-point scale. (2) Profile of Mood States (POMS) [2]. Sixty-five items were presented. Most items were related to five negative factors (Anger, Depression, Tension, Fatigue, and Confusion) and a positive one (Vigor). The intensity of each item was rated on a five-point scale. Both questionnaires were programmed on portable computers (GRiD Compass II, GRiD Systems Corporation, Mountain View, CA). Instructions preceded each questionnaire. Individual items, accompanied by the appropriate rating scale, appeared on the screen one at a time. No items could be omitted, and out-of-range responses were not accepted.

Procedure

Test. Two days before the start of each test iteration, baseline symptom and mood ratings were obtained under hot-dry environmental conditions. During the test iterations, ratings were obtained at six-hour intervals and whenever a subject ended his participation. All ratings were retrospective, encompassing the time since arrival at the test site or since the previous questionnaire administration.

Data analysis. Some of the data collected were excluded from analysis. All data from one subject (#6) were excluded because it was learned that he had contracted a cold prior to the start of the second test. In addition, data from those administrations that did not include the remaining subjects in both solution conditions were excluded. Since most subjects terminated their participation at some point before the end of an iteration, only three administrations were analyzed. Thus data from 11 subjects for the baseline administrations (PRE), first six-hour administrations (6H), and the administrations that occurred whenever subjects terminated their participation (POST) were analyzed. Questionnaire item ratings were analyzed individually and combined to provide a total score for each questionnaire. The Total Symptom Score (ESQ) was computed by summing all the individual ratings. The Total Mood Disturbance Score was computed as described by McNair, Lorr, & Droppleman [2]. This essentially involved subtracting the positive factor (Vigor) score from the negative factor scores.

Questionnaire items and total scores were submitted to two levels of statistical analysis [3]. (1) Two-way repeated-measure analysis of variance (ANOVA). Emphasis was on within-subjects main effects of the two types of solutions (S) and interactions of the type of solution with changes over the three questionnaire administrations (SA). In addition, a grouping factor (O) was created to determine whether the order in which the solutions were consumed had any effect. (2) Post hoc (Tukey HSD) tests. For more exact specification of the nature of significant ($p<0.05$) ANOVA effects, all possible combinations of levels of the within-subjects and between-groups factors were compared.

RESULTS

General Effects

Compared with the control solution, the NBC solution was associated with lower symptom intensity and improved mood. Overall, both the Total Symptom and the Total Mood Disturbance Scores were significantly ($p<0.05$) lower in the NBC solution condition. Table 1 shows this effect was primarily due to changes that occurred after six hours. At the six hour administration, no significant differences from baseline were seen for either the symptom or mood measure. After six hours (POST), there was still no significant change in mean intensity in the NBC solution condition while there was a significant increase in both measures ($p<0.01$) in the the control condition. At termination, the mean symptom score in the NBC solution condition was only 63% of that reported in the control condition and the mood disturbance score, which showed an even greater difference ($p<0.01$), was 39% of that seen in the control condition. Figure 1 shows the patterns of change over time. It can be seen that there is considerable similarity between general changes in symptoms and mood.

No significant effects related to the order in which the solutions were ingested were seen for either the symptom or mood score.

Individual Items

Order effects. Seven percent of the ESQ items and 12% of the POMS items that showed significant effects for the two solution conditions also showed significant differences depending on the order in which the solutions were

tested. The primary order effect appeared to involve items related to fatigue, with the differences being greatest at termination. For these items, beneficial effects of the NBC solution were seen if the solution was consumed in the first iteration and water in the second. When the NBC solution was consumed in the second iteration and water in the first, no differences were seen between the solutions.

ESQ and POMS items showing significant order effects are presented in Appendices 7 and 8. These items will be excluded from further consideration.

Primary effects. Fifteen symptom and mood items showed solution effects that did not depend on the order in which the solutions were presented. These items were combined, one redundant item eliminated, and the remaining items reduced to six primary effects. These are presented in Table 2, together with significance levels. The first five columns show various types of differences between control and NBC solution conditions: overall differences between the solution conditions (S), in the way the two conditions changed over administrations (SA), and in the differences between the solutions at each of the questionnaire administrations (PRE, 6H, POST). The last four columns show the differences between the last two administrations (6H, POST) from the baseline administration (PRE) for both the control and the NBC solution condition.

All 15 items indicated that physical and mental states deteriorated less in the NBC than the control condition; none of the items suggested any adverse effects of the solution. The beneficial effects were most apparent for perceptual-motor and cognitive items. There were no significant increases relative to baseline in the NBC group, while there were significant

increases in the control condition by termination for all items but one ("shaking hands"). These different changes over time produced significant differences between the conditions at termination. Mean intensity at termination in the NBC condition ranged from 14% ("confusion") to 37% ("poor concentration", "poor coordination") of that in the control condition. Emotional and thermal items showed significantly lower overall intensity ratings in the NBC condition but no significant differences at specific points. Nevertheless, intensity at termination for the NBC condition ranged from a low of 8-9% of that seen in the control condition ("stomach ache", "grouchiness") to 79% ("hunger").

Only one item, "fatigue", showed significant increases in both the NBC ($p<0.05$) and control ($p<0.01$) conditions. While the NBC condition was associated with significantly ($p<0.05$) lower fatigue, the nature of the effect was not clear. A number of other symptom and mood items related to fatigue showed significant effects that depended on the order in which the solutions were tested.

DISCUSSION

The NBC solution appeared to have beneficial effects on a number of symptoms and adverse mood states. For the first six hours, the NBC Nutrient solution offered no apparent advantage over the control solution. Thereafter, self-report measures showed that perceptual-motor, cognitive, emotional, gastrointestinal, and thermal problems were eliminated or attenuated when the solution was consumed. No harmful effects were reported.

However, these findings do not constitute an unqualified endorsement of the solution.

For one, it is possible that the subjects were biased in favor of the NBC solution. The inadvertent omission of artificial sweetening from the control solution made it readily apparent to the subjects that they were consuming colored, flavored water. Nevertheless, the data do not suggest that the subjects were indiscriminately reporting higher levels of symptomatology and mood distress in the control condition. Items showing any kind of primary solution effects comprised only 13% of the ESQ and 9% of the POMS items. Moreover, many of the effects are consistent with lowered blood sugar [5] if not electrolyte imbalance. Finally, objective measures seem to corroborate some effects. For example, the lower level of cognitive problems reported here for the NBC condition is consistent with the findings reported in the previous section (Cognitive and Motor Performance Tests).

In addition, it is difficult to generalize from the test conditions to the NBC environment for which the solution is intended. Soldiers in running shoes and shorts do not experience all the same problems as those encapsulated in the full chemical protective ensemble (MOPP4). When symptom and mood questionnaires were administered in a series of field tests, five basic symptoms were shown to be related to endurance in test after test [5-9]. Breathing problems (painful breathing, difficulty breathing, shortness of breath), headache and nausea were consistently greater in casualties (voluntary/medical terminations) than in survivors. There were no significant effects of the solution on any of these items. The effect of the solution on respiratory problems could not be assessed; there was no

significant increase over the course of the test (Appendix 8). Headache and nausea did show significant increases. Since symptomatic treatment was offered by the medical monitor, it is possible that this obscured any differential effects of the NBC solution and control solution. However, such interventions also occurred in the above mentioned NBC field tests. Therefore, it appears that two of the five basic MOPP4 symptoms were unaffected by the solution and the other three could not be assessed. Both the positive findings and the confounding factors suggest that a truly double-blind test of control vs the NBC solution (two "different" solutions) be conducted in MOPP4. In addition, this would offer an opportunity to address some questions raised by the findings of this study. For example, several items related to fatigue showed differences between the solutions only when the NBC solution was administered in the first iteration. Does that mean that the NBC solution has effects that are negated by cumulative fatigue?

CONCLUSIONS

1. The NBC solution offered no apparent advantage over the control solution during the first six hours of light exertion in a hot, dry environment. No significant increases in symptom intensity or mood disturbance occurred with either solution.

2. After six hours, the NBC solution appeared to help maintain symptom and adverse mood intensity near baseline levels while significant increases

occurred for both measures when only the control solution was consumed. Perceptual-motor, cognitive, emotional, gastrointestinal, and thermal items were primarily affected. No adverse effects were reported for the NBC solution.

3. The extent to which the NBC solution will aid soldiers in NBC environments is questionable at present. Symptoms that appear to be basic to endurance in MOPP4 were either not improved (headache, nausea) or not produced by the test conditions (respiratory problems).

REFERENCES

1. Kobrick JL, Sampson JB. New inventory for the assessment of symptom occurrence and severity at high altitude. Aviat Space Environ Med 1979;50:925-929.

2. McNair DM, Lorr M, Droppleman LF. EITS Manual for the Profile of Mood States (POMS). San Diego: Educational and Industrial Testing Service, 1981.

3. Winer BJ. Statistical Principles in Experimental Design. New York: Wiley, 1971.

4. Permutt MA. Postprandial hypoglycemia. Diabetes 1976;25:719-733.

5. Munro I, Rauch TM, Tharion W, Banderet LE, Lussier AR, Shukitt B. Factors limiting endurance of armor, artillery, and infantry units under simulated NBC conditions. Proceedings, Army Science Conference, 17-19 June 1986;111:85-96.

6. Munro I, Rauch TM, Banderet LE, Lussier AR, Tharion WJ, Shukitt BL. Psychological effects of sustained operations in a simulated NBC environment on M1 tank crews. (Technical Report No. T26-87) Natick, MA: US Army Research Institute of Environmental Medicine, 1987.

7. Posen K, Munro I, Mitchell G, Satterthwaite J. Innovative test of physiological and psychological effects of NBC and extended operations on mechanized infantry squads (Technical Report TRADOC No. 000000663, USAIB No. 3807) Ft. Benning, GA: US Army Infantry Board, 1986.

8. Tharion WJ, Rauch TM, Munro I, Lussier AR, Banderet LE, Shukitt B. Psychological factors which limit the endurance capabilities of armor crews operating in a simulated NBC environment. (Technical Report No. T14-86) Natick, MA: US Army Research Institute of Environmental Medicine, 1986.

9. Rauch TM, Banderet LE, Tharion WJ, Munro I, Lussier AR, Shukitt B. Factors influencing sustained performance capabilities of 155mm Howitzer sections in simulated conventional and chemical warfare environments. (Technical Report No. T11-86) Natick, MA: US Army Research Institute of Environmental Medicine, 1986.

TABLE 1. GENERAL SYMPTOM AND MOOD EFFECTS OF THE NBC NUTRIENT SOLUTION. Pre-test mean total scores compared with those obtained after six hours and at termination for both the control and the NBC Nutrient solution conditions.

		MEAN INTENSITY ±SD		
		PRE	6H	POST
				**
MOOD DISTURBANCE SCORE	Control	4.82	6.55	33.91**
		±19.71	±20.33	±26.26
	NBC	1.27	- 3.55	13.27
		±11.79	± 9.06	±13.96
SYMPTOM SCORE	Control	30.55	32.00	62.27**
		± 8.59	±20.26	±35.87
	NBC	24.91	23.64	39.82
		±10.67	± 8.99	±19.44

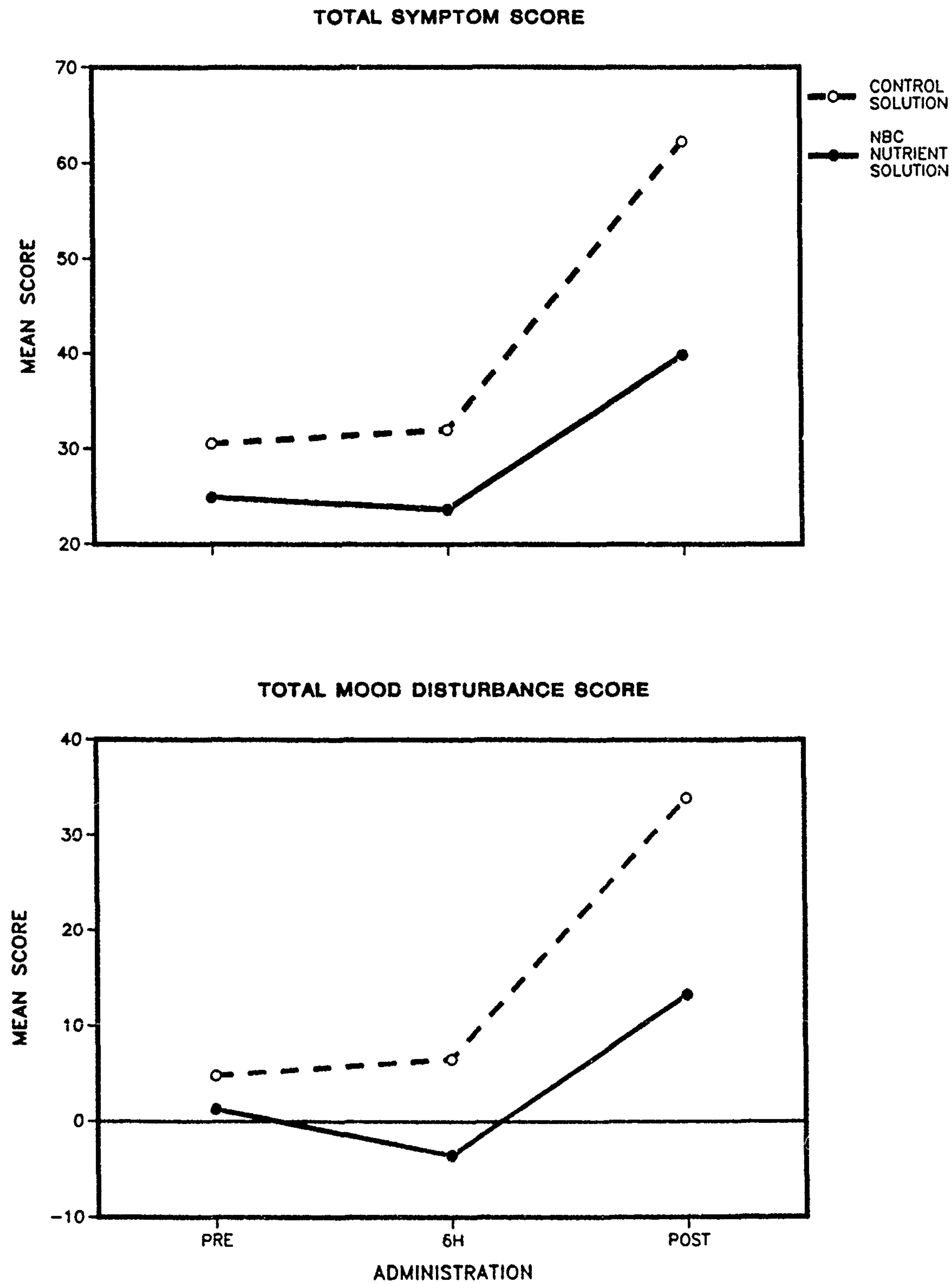
[1]Asterisks indicate _post hoc_ test significance levels (*=$p<0.05$, **=$p<0.01$).

TABLE 2. COMBINED SYMPTOM AND MOOD ITEMS SHOWING SIGNIFICANT NBC NUTRIENT SOLUTION EFFECTS.

	CONTROL vs NBC					PRE-TEST vs TEST			
						Control		NBC	
	S	SA	PRE	6H	POST	6H	POST	6H	POST
FATIGUE									
fatigue	*	**	NS	NS	**	NS	**	NS	*
PERCEPTUAL-MOTOR									
dim vision	NS	*	NS	NS	**	NS	**	NS	NS
poor coordination	**	*	NS	NS	*	NS	**	NS	NS
shaking hands	**	NS	NS	NS	NS	NS	NS	NS	NS
COGNITIVE									
poor concentration	NS	*	NS	NS	**	NS	**	NS	NS
confusion	*	NS	NS	NS	*	NS	*	NS	NS
GASTROINTESTINAL									
stomach ache	*	**	NS	NS	**	NS	**	NS	NS
hunger	*	NS	NS	NS	NS	NS	NS	NS	NS
EMOTIONAL									
irritability	*	NS	NS	NS	NS	NS	NS	NS	NS
grouchiness	*	NS	NS	NS	NS	NS	NS	NS	NS
resentfulness	*	NS	NS	NS	NS	NS	NS	NS	NS
badtemperedness	NS	*	NS	NS	NS	NS	NS	NS	NS
THERMAL									
warmth	*	NS	NS	NS	NS	NS	NS	NS	NS
feverishness	*	NS	NS	NS	NS	NS	NS	NS	NS

[1] S=solution main effect, SA=solution x administration interaction. Asterisks indicate significance levels (NS=p>0.05 , *=p<0.05, **=p<0.01).

FIGURE 1. GENERAL SYMPTOM AND MOOD EFFECTS



PSYCHOLOGICAL ASSESSMENT

FOOD ACCEPTANCE
AND
SUBJECTIVE SELF-REPORTS

METHODS

Within-Test Measures

At the start of the test and every three hours thereafter, an evaluation of the acceptance and perceived sensory qualities of the NBC Nutrient solution and/or control solution was conducted. In addition, subjective self-reports of internal bodily states were collected. For these evaluations, subjects were administered a brief 10-item questionnaire (Appendix 9). Subjects were seated at a table and asked to complete the first 4 items of the questionnaire. These 4 items required the subjects to rate their current level of thirst, hunger, alertness and strength. After responding to these items, subjects were asked to taste the NBC Nutrient solution or the control solution from a freshly filled canteen and to complete the remaining items of the questionnaire. The latter items required the subjects to rate the hedonic and sensory aspects of the NBC Nutrient solution or control solution. Specific aspects rated were "overall liking" (or disliking), "sweetness", "saltiness", "flavor intensity", "sourness", and temperature. A nine point hedonic scale (1) was used to assess liking. All of the other items, except that for temperature, employed 10-point category scales, with zero (0.0) reflecting absence of the attribute and 10 reflecting an extremely intense perception of the attribute. The temperature scale was a 9-point bidirectional category scale (1=extremely cool, 5=neutral, 9=extremely warm).

Post-Test Measures

At the completion of the test, a post-test questionnaire was administered (Appendix 10). This questionnaire addressed issues related to the acceptance of the NBC Nutrient solution as compared to the control solution. Multiple-choice questions with scaled responses and open-ended questions were used.

RESULTS

Within-Test Measures

Figures 1-10 are plots of the mean ratings across subjects for each of the dependent variables as a function of time. Two-way analyses of variance were conducted on each of the variables to assess the effect of both fluid condition and time. However, while the data in Figures 1-10 are based on all subjects still remaining in the test at each time period, analyses of variance were conducted only on data collected through the first 15 hours of the test. The reason for this is that the data contained in the remaining 9 hours is based on such few subjects (4 or less) in each condition that the power of the test would suffer by including these data.

Hunger ratings. Hunger ratings are shown in Figure 1. As would be expected, hunger increased as a function of time for subjects in both fluid conditions. Analysis of variance showed the main effect of time on hunger ratings to be highly significant ($F=11.64$; $df=35,5$; $p<0.001$). Although the data in Figure 1 seem to show an absolute difference in hunger ratings between the two fluid conditions, with the control solution showing greater hunger at each time period, neither the main effect of fluid condition nor the fluid X time interaction effect was statistically significant.

Thirst ratings. The data for thirst sensations are shown in Figure 2. As can be seen, thirst sensations significantly decreased over time ($F=4.79$; $df=35,5$; $p<0.002$), reflecting the effects of forced drinking to ensure euhydration. Thirst sensations did not differ significantly between the two fluid conditions over the first 15 hours, although it appears that the functions diverge after 18 hours. Unfortunately, there are too few data points to draw any statistically valid conclusions about this apparent difference.

Self-reports of alertness. Self-reported alertness is shown in Figure 3. A gradual decline in subject's ratings occurred as a function of time in both fluid conditions through the first 15 hours ($F=6.41$; $df=35,5$; $p<0.001$). However, there was no main effect of fluid condition or fluid X time interaction during this period. After 18 hours, self-reported alertness appears to increase in both fluid conditions, perhaps reflecting an anticipatory end-of-test effect.

Self-reports of physical strength. As with self-reported alertness the self-reports of physical strength shown in Figure 4 decline as a function of time during the first 15 hours ($F=8.49$; $df=35,5$; $p<0.001$). Again, there is no main effect of fluid nor fluid X time interaction, and there is an apparent increase in self-reported physical strength in the NBC Nutrient solution condition during the last 3-6 hours of the test.

Fluid Temperature. Figure 5 shows the data for judgments of fluid temperature. A two-way ANOVA on these data failed to show any effect of fluid condition or time on the judged temperature of the fluids during the first 15 hours. The data points at 21 hours appear erratic and are likely due to the small number of subjects contributing to the data.

Sensory acceptance. Judgments of liking/disliking of the fluids over time are shown in Figure 6. A large and statistically significant difference in liking for the two fluids can be seen ($F=16.19$; $df=7,1$; $p<0.005$). The NBC Nutrient solution was greatly preferred to the control solution throughout the test. There was also a significant main effect of time on acceptance ratings ($F=5.35$, $df=35,5$; $p<0.001$) and a significant fluid X time interaction effect ($F=3.02$; $df=35,5$; $p<0.02$). These effects can be seen in Figure 6 as the rather large and systematic decline in the acceptance of the NBC Nutrient solution over the first 15 hours, as contrasted with the much more moderate decline in the acceptance of the control solution over this time. The decline in the acceptance of both fluids over time is probably due to flavor monotony and the sensory-specific satiety that results from prolonged consumption of the same fluid. It should be noted that after 15 hours, the NBC Nutrient solution appears to show some recovery of acceptance, but with the small number of subjects it is difficult to determine unequivocally.

Sweetness. The sweetness data in Figure 7 reflect an expected significant difference in perceived sweetness between the two fluids ($F=30.86$, $df=7,1$; $p<0.001$), with the fructose-sweetened NBC Nutrient solution being judged much sweeter than the unsweetened but flavored control solution. Neither the main effect of time nor the interaction effect was significant.

Saltiness. As with judgments of sweetness, the data in Figure 8 show a much greater perceived saltiness for the NaCl-containing NBC nutrient solution than for the unsalted, flavored control solution ($F=9.04$; $df=7,1$; $p<0.020$). Moreover, there was also a main effect of time ($F=3.67$; $df=35,5$;

$p<0.009$), as reflected in the gradual decline in perceived saltiness for both fluids over time.

Flavor intensity. The judgments of flavor intensity in Figure 9 show the same significant fluid effect as for sweetness and saltiness. The NBC nutrient solution was perceived as having more flavor intensity than the flavored control solution ($F=14.8$, $df=7,1$; $p<0.006$). As with judgments of saltiness, a gradual but significant decrease in flavor intensity judgments over time ($F=4.83$; $df=35,5$; $p<0.002$) can be seen in Figure 9.

Sourness. Figure 10 shows the sourness judgments over time. Unlike the judgments of sweetness, saltiness and flavor intensity, there was no main effect of fluid on sourness judgments, i.e., they were perceived to be equally sour. However, the judgments of sourness for both fluids declined significantly over time ($F=4.93$; $df=35,5$; $p<0.002$).

Correlations among dependent variables. Tables 1 and 2 show Pearson product-moment correlation coefficients for the relationships among the dependent variables of thirst, hunger, self-reported alertness and self-reported strength for the control solution (Table 1) and NBC nutrient solution (Table 2) conditions. The data in Tables 1 and 2 are remarkably similar in showing no significant association among these 4 variables, except for the strong positive association between self-reported strength and alertness.

Tables 3 and 4 show Pearson product-moment correlation coefficients among the six sensory variables for the control solution (Table 3) and NBC nutrient solution (Table 4) conditions. Examination of Table 3 reveals independence between judgments of the acceptance (like/dislike) of the

control solution and each of the other sensory variables. Similarly, judgments of the temperature of the fluid are independent of all other sensory attributes. In contrast the judgments of perceived sweetness, saltiness, flavor intensity and sourness were all significantly correlated with one another (positive association). Examination of Table 4 also reveals an independence between acceptance judgments and each of the other sensory variables and between temperature judgments and each of the other sensory variables, except perceived sourness. The latter correlation, between temperature and sourness, is positive and highly significant, although a theoretical explanation is not readily apparent. The only other statistically significant associations in Table 4 are between judgments of perceived sweetness and flavor intensity and between perceived sweetness and sourness. The former association is positive, while the latter is negative. The failure to find significant associations among perceived saltiness, flavor intensity and sourness in these data, in contrast to the control solution data of Table 3, is probably attributable to the overall greater intensity of each of these variables in the NBC Nutrient solution, making discrimination among the variables easier and fostering greater independence of judgment than in the control solution condition.

Post-Test Measures

Matched t-tests were performed on the data collected through the post-test questionnaires (Appendix 9) to assess differences between the two fluid conditions. Statistically significant differences between the control solution and NBC Nutrient solution were found for judgments of fluid

acceptance (Q1: $t=-3.24$, $df=11$, $p<0.01$), perceived energy provided by the fluid vs "water" (Q3: $t=2.86$, $df=11$, $p<0.05$) and perceived psychological "lift" provided by the fluid (Q6: $t=-3.55$, $df=11$, $p<0.01$). In each case the NBC Nutrient solution was more acceptable, provided relatively more energy than "water" and gave more of a psychological "lift." No statistical difference was found for judgments of relative acceptance vs water, whether the sole use of the fluid in the field would be a problem, and/or the nature and quantity of canteens of the fluid desired vs water.

DISCUSSION

The combined results of the subjective evaluations are internally consistent. Although they do not show a major beneficial effect of the NBC Nutrient solution over the control solution, nevertheless, it is clear that the NBC Nutrient solution was preferred over the control solution, and there may have been some beneficial cognitive effects on perceived energy, psychological "lift", etc.

The significant increase in hunger and decreases in self-reported alertness and strength over time are consistent with expected metabolic and physiological effects of consuming water or a calorie-containing fluid for an extended period of time while treadmill walking in heat and without sleep or prolonged rest. Although the data from the post-test questionnaire provide some evidence of a beneficial effect of the NBC Nutrient solution on perceived energy and providing a psychological "lift", the within-test data show only a general trend that the NBC Nutrient solution amelicrates these effects.

FOOD ACCEPTANCE AND SUBJECTIVE SELF-REPORTS

Although it would normally be expected that thirst would increase under the stated test conditions, the observed decrease in thirst sensations over time in this study is directly attributable to the procedure of forced drinking that was utilized to effect euhydration for all subjects throughout the test. The latter procedure eliminates the major physiological antecedants of thirst sensations. The fact that thirst sensations not only failed to increase, but actually decreased over time in this study is probably attributable to the cognitive components of subjective thirst, i.e., the subjects were forced to drink continuously throughout the study and knew that fluid was always available to them.

Concerning the sensory and hedonic aspects of the NBC Nutrient solution vs control solution, it is clear that subjects could easily distinguish between the two fluids. This discrimination was not due to any perceived difference in the temperature of the fluids, which showed no effect by fluid or time. Rather, subjects could distinguish the NBC Nutrient solution by its significantly more intense sweetness, saltiness and lemon-lime flavor. The ability of subjects to easily distinguish between the test fluids and, thereby, between the test conditions, demands that all of the data from this study be viewed carefully for possible subject biases, to ensure that cognitive variables may not be influencing the results.

In addition to easily discriminating between the two fluids, the acceptance data from both the within-test and post-test questionnaires are clear in showing that subjects preferred to drink the NBC Nutrient solution over the control solution. Although preference itself may not be the most critical factor in developing a nutrient replacement fluid, nevertheless,

preference is very frequently correlated with voluntary consumption, and the latter is critical under conditions of high heat stress and sweating.

Of psychophysical interest in these sensory data, are the significant declines in perceived saltiness, sourness and flavor intensity over time. These data reflect a classic sensory adaptation phenomenon, resulting from repeated stimulation of the receptors responsible for mediating these sensations. Such adaptation frequently leads to sensory specific satiety, in which foods or fluids that have the same or similar flavor are no longer consumed with the same frequency. The forced drinking procedure of this study obviates any possibility of observing such a decline in consumption, but these data suggest that under completely *ad libitum* conditions, sensory specific satiety may result from prolonged consumption of these fluids, causing reduced consumption and contributing further to possible voluntary dehydration. The interaction of this effect with the effect of increased consumption resulting from an initially more acceptable fluid must be studied before conclusions about net gains in consumption can be drawn.

CONCLUSIONS

1. The NBC Nutrient solution was reported as having more flavor, sweetness, and saltiness, and was liked more in comparison to the control solution.

2. Over time, subjects reported no change in solution temperature and their perceptions of acceptability, saltiness, flavor, and sourness decreased. Also, subjects' self-reported hunger increased and their thirst, alertness, and strength decreased over time.

3. Strong positive correlations between self-reported alertness and self-reported strength were found for both the control and the NBC solution conditions.

4. Acceptance and temperature were independent of the other sensory attributes (sweetness, saltiness, flavor intensity, and sourness) for both the control and the NBC solution conditions, with the exception of a positive correlation between temperature and sourness for the NBC solution condition.

5. For the control solution condition, sweetness, sourness, flavor intensity, and saltiness were positively related to each other. For the NBC solution condition, sweetness and flavor intensity were positively related and sweetness and sourness were negatively related.

6. Data from the post-test questionnaire including fluid acceptance, perceived energy, and perceived psychological "lift" provided by the fluid, indicated that NBC Nutrient solution was more favorable in comparison to the control solution.

REFERENCES

1. Peryam DR, Girardot NF. Advanced taste-test method. Food Engineerirg 1952;24:58-61.

Table 1. Pearson product-moment correlation coefficients for the linear associations among the dependent variables of self-reported strength, alertness, thirst and hunger for the control solution condition.

	Strength	Thirst	Hunger
Alertness	.94**	.16	-.26
Hunger	-.26	.10	
Thirst	.23		

** Two-tailed significance at the $p<0.01$ probability level.

Table 2. Pearson product-moment correlation coefficients for the linear associations among the dependent variables of self-reported strength, alertness, thirst and hunger for the NBC Nutrient solution condition.

	Strength	Thirst	Hunger
Alertness	.87**	.14	-.13
Hunger	-.23	.09	
Thirst	.22		

** Two-tailed significance at the $p<0.01$ probability level.

Table 3. Pearson product-moment correlation coefficients for the linear associations among the sensory attributes of the control solution.

	Temperature	Sourness	Flavor Intensity	Saltiness	Sweetness
Like/Dislike	.30	.15	.22	.13	.22
Sweetness	.15	.84**	.74**	.84**	
Saltiness	.17	.88**	.68**		
Flavor Intensity	.04	.73**			
Sourness	.17				

** Two-tailed significance at the $p<0.01$ probability level.

Table 4. Pearson product-moment correlation coefficients for the linear associations among the sensory attributes of the NBC Nutrient solution.

	Temperature	Sourness	Flavor Intensity	Saltiness	Sweetness
Like/Dislike	-.16	-.13	-.20	.26	-.21
Sweetness	-.18	-.30**	-.73**	-.08	
Saltiness	-.09	.27	-.16		
Flavor Intensity	-.01	-.03			
Sourness	.54**				

** Two-tailed significance at the p<0.01 probability level.

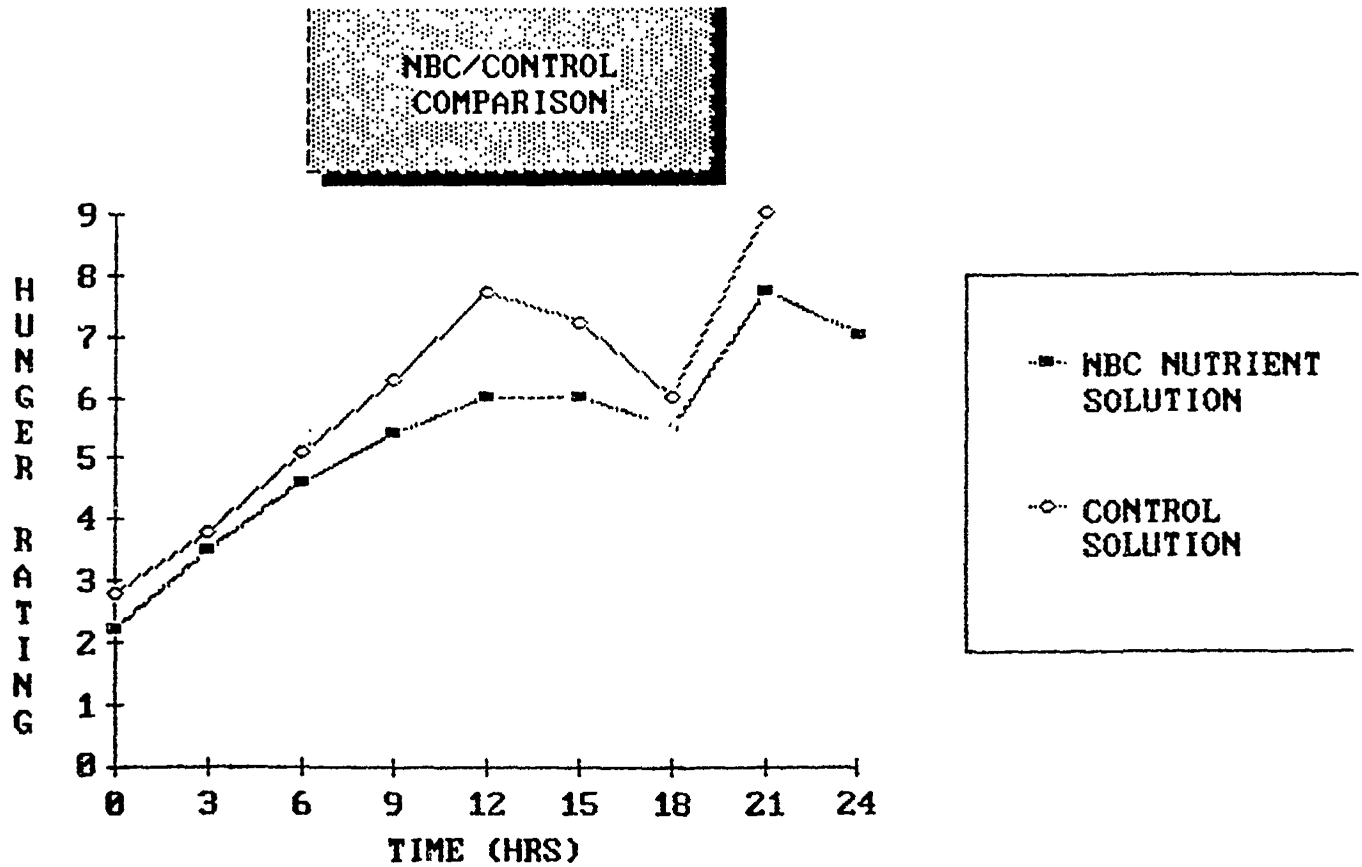


Figure 1. Self-reported hunger ratings as a function of time.

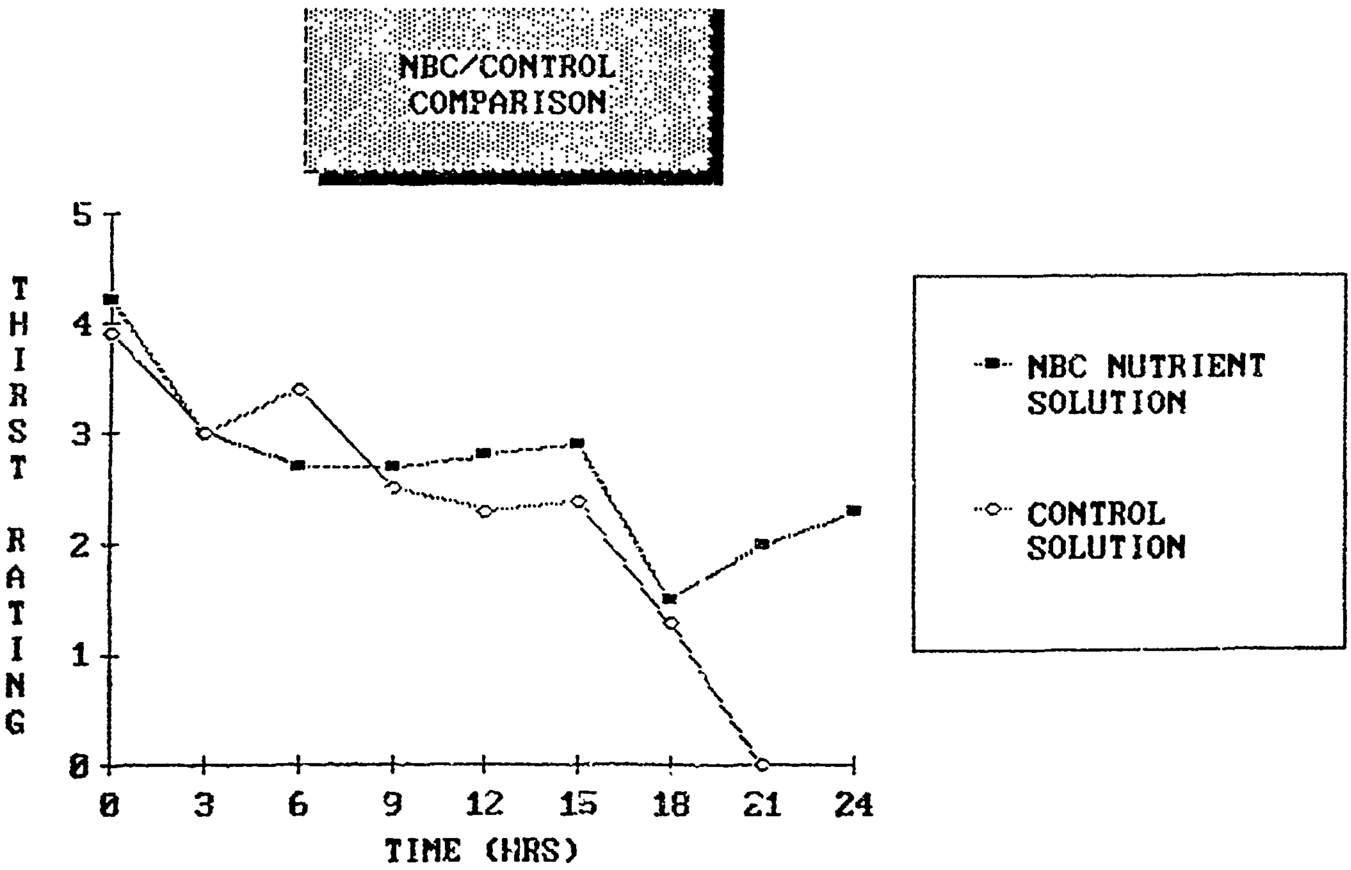


Figure 2. Self-reported thirst ratings as a function of time.

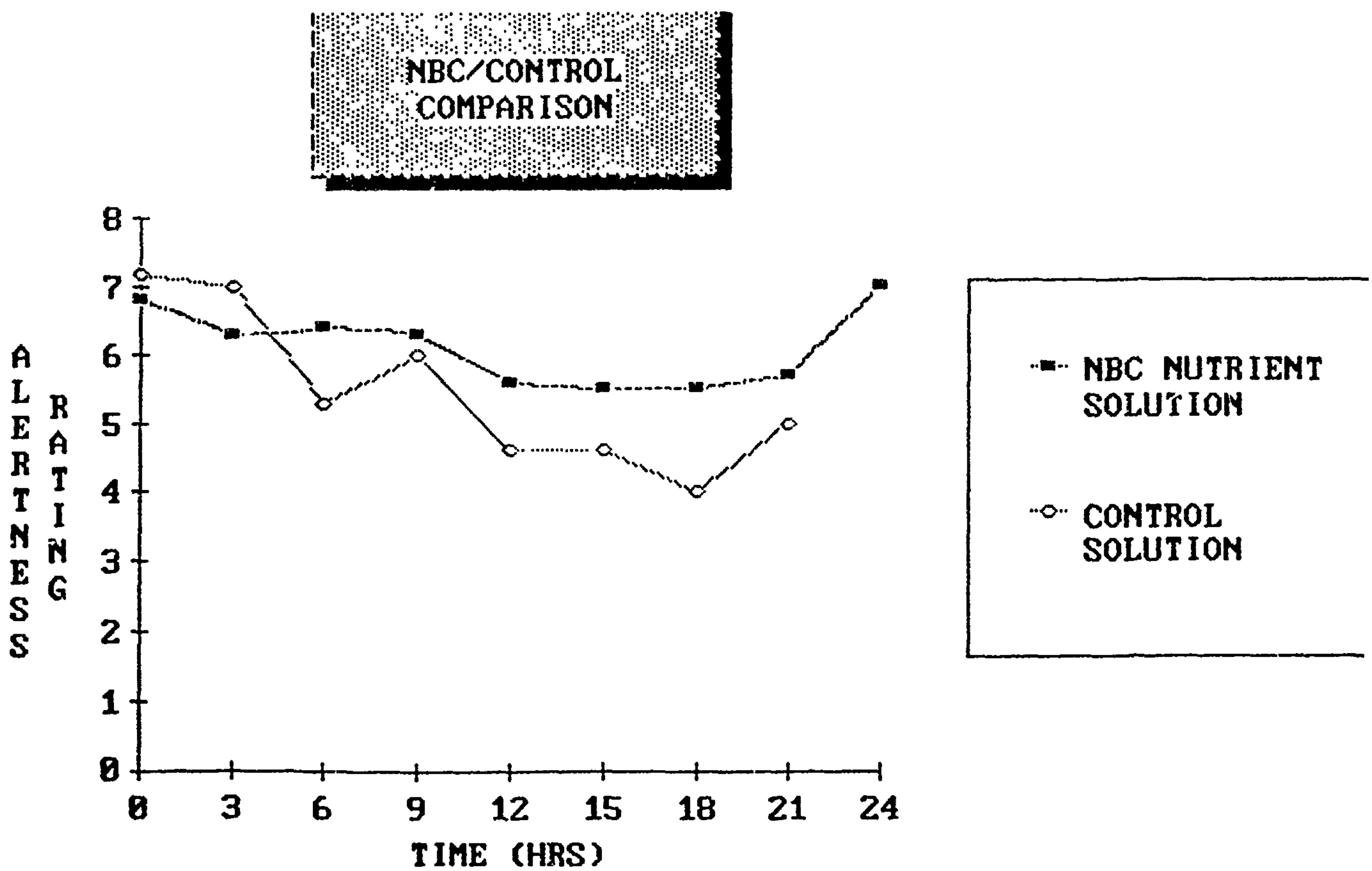


Figure 3. Self-reported alertness ratings as a function of time.

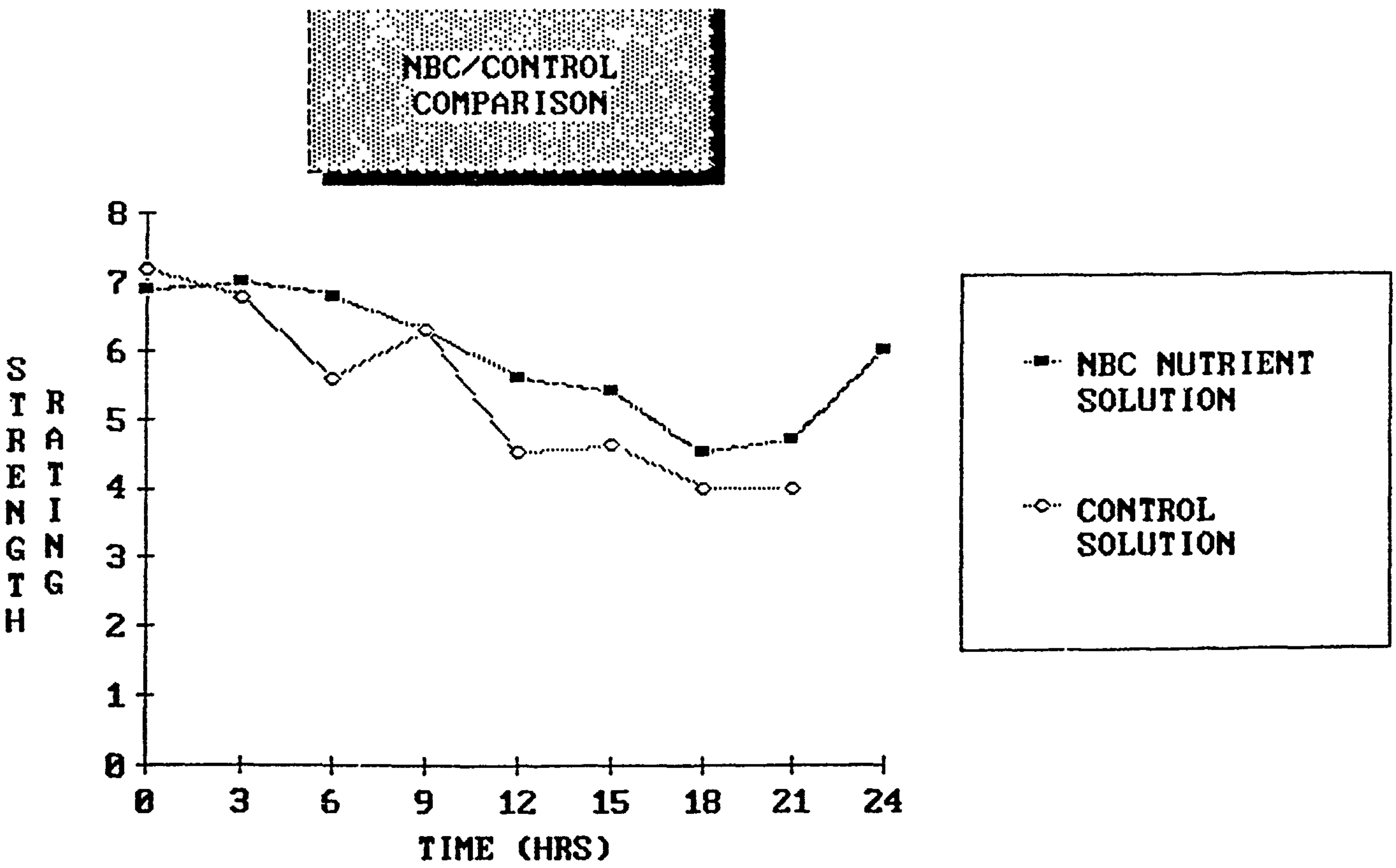


Figure 4. Self-reported strength ratings as a function of time.

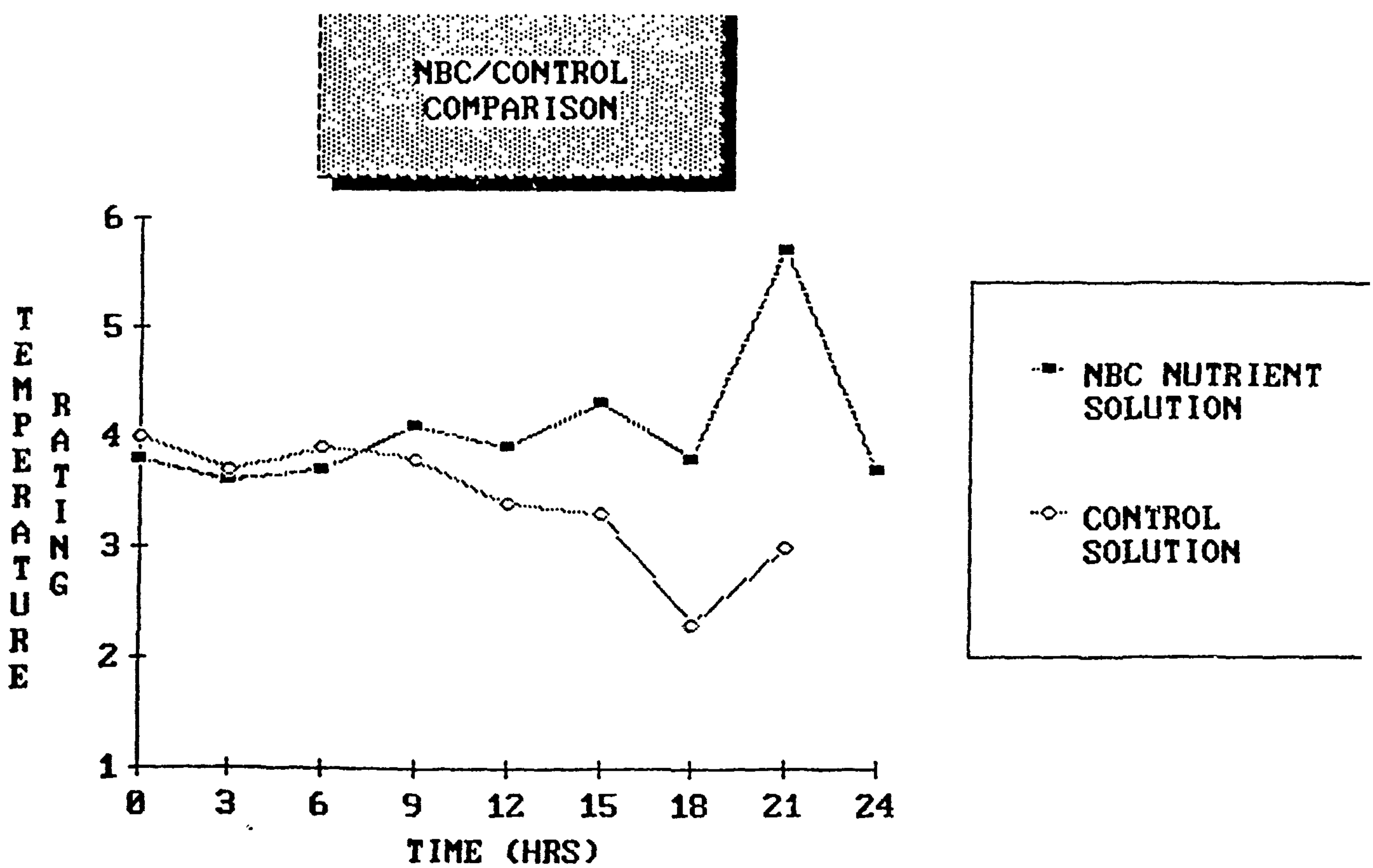


Figure 5. Perceived fluid temperature ratings as a function of ti

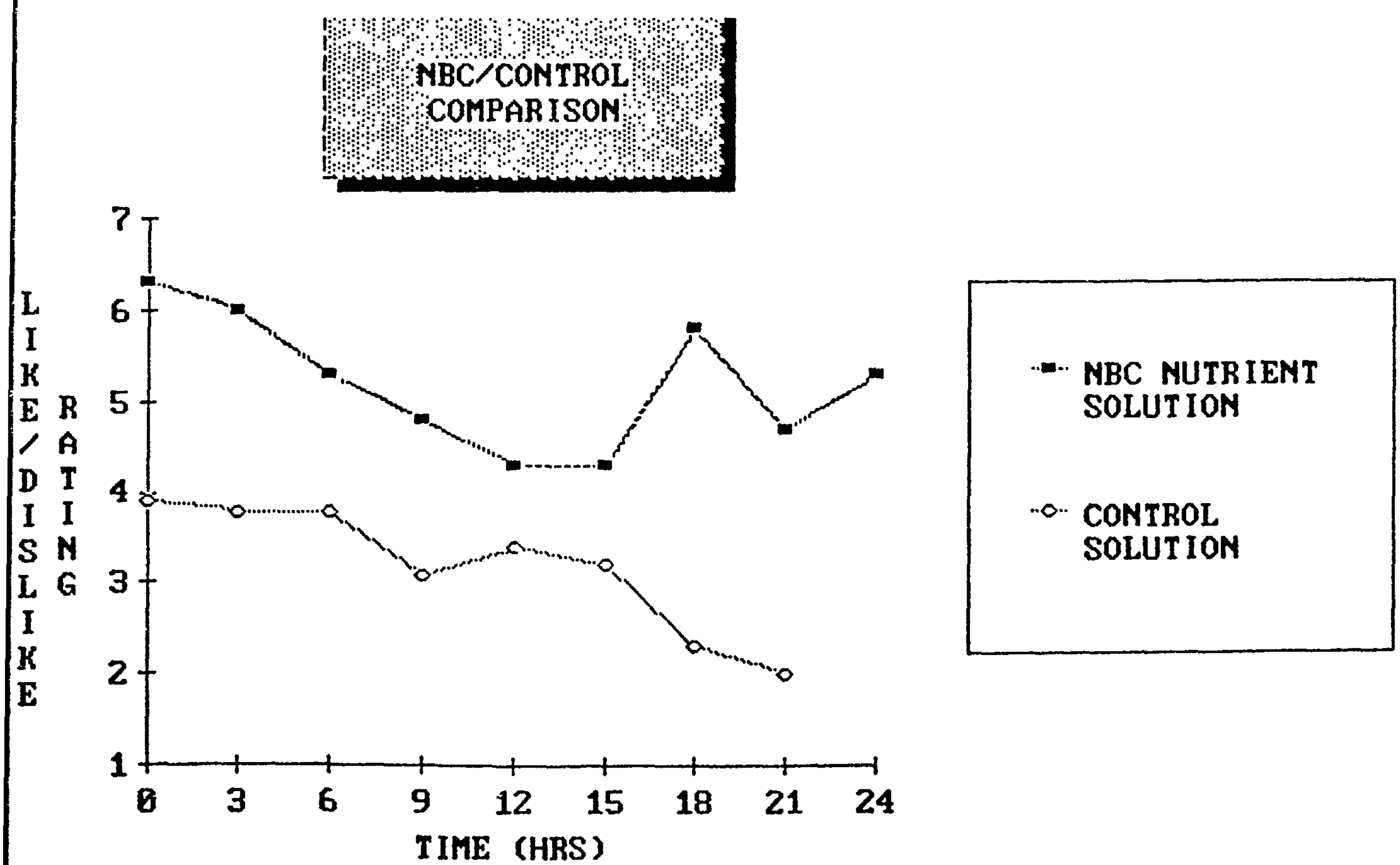


Figure 6. Perceived sensory acceptance ratings as a function of time.

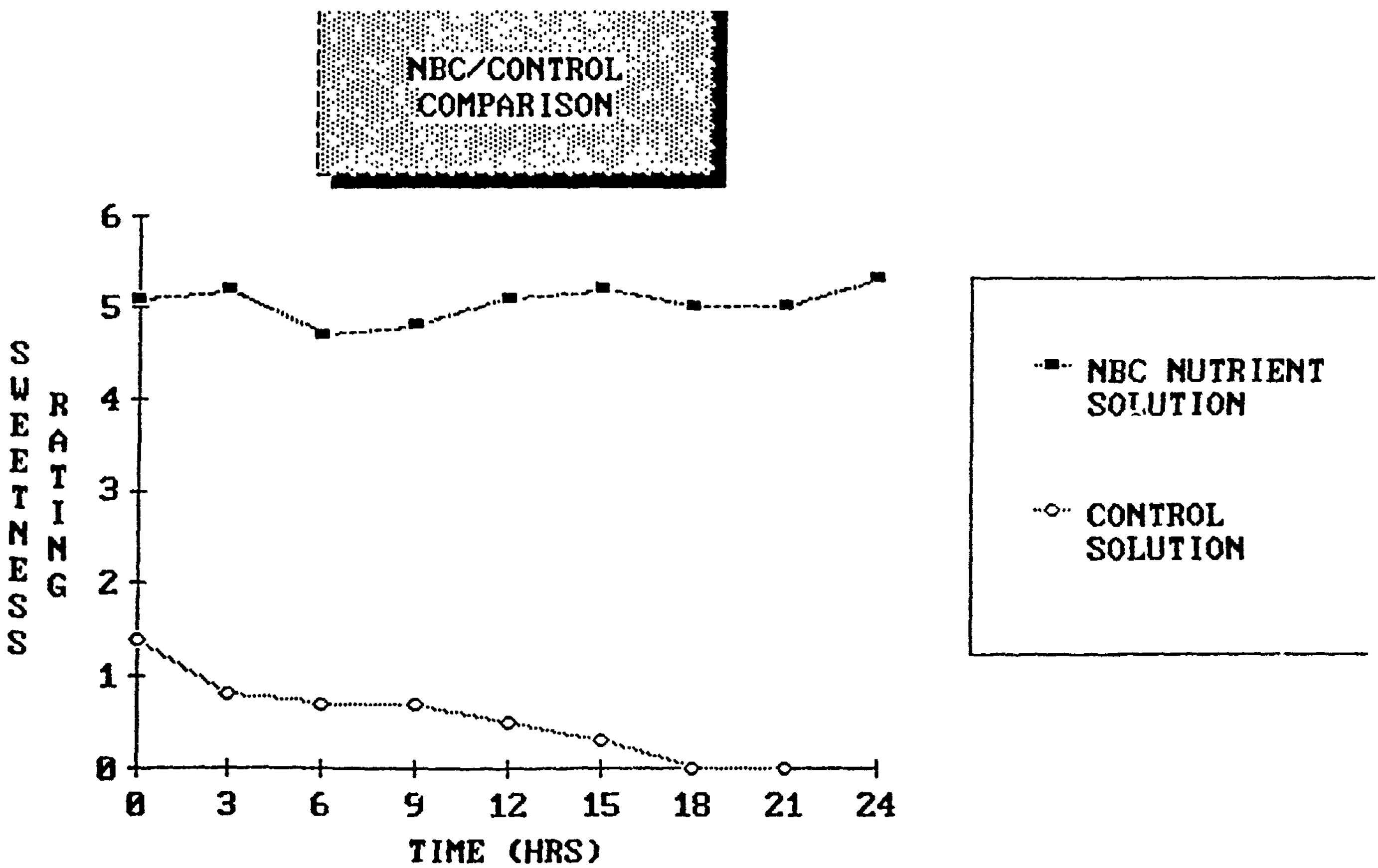


Figure 7. Perceived sweetness ratings as a function of time.

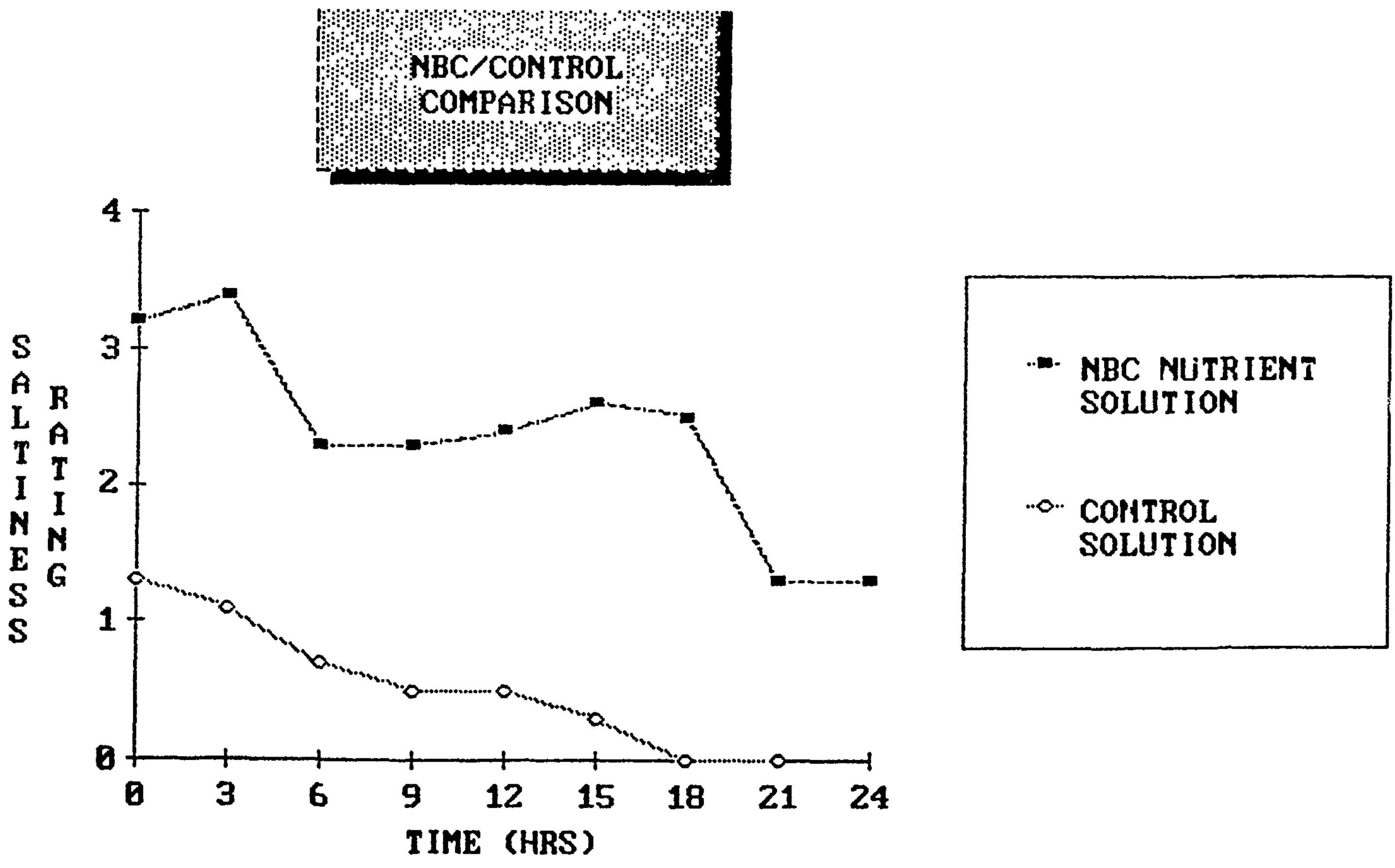


Figure 8. Perceived saltiness ratings as a function of time.

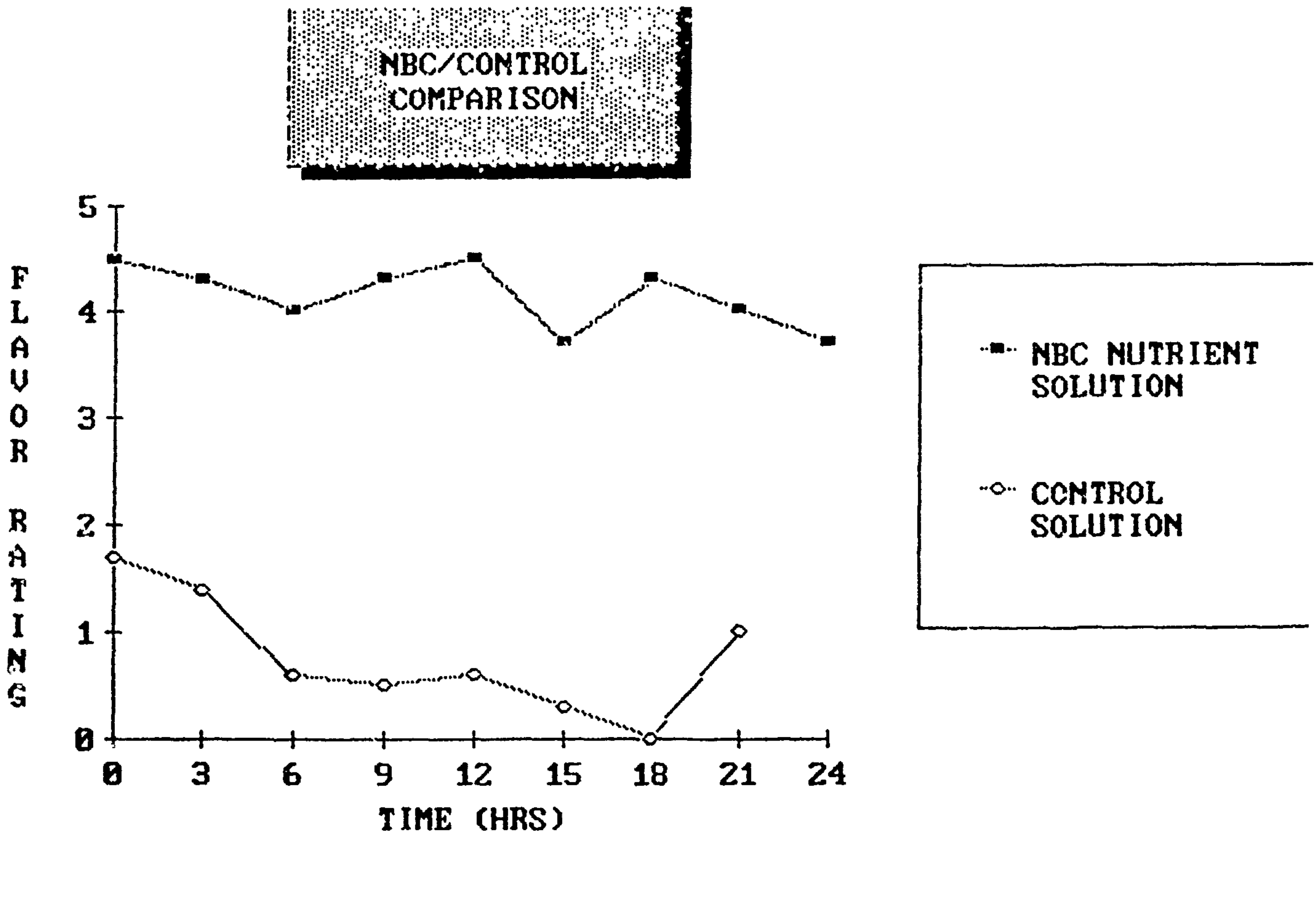


Figure 9. Perceived flavor intensity ratings as a function of time

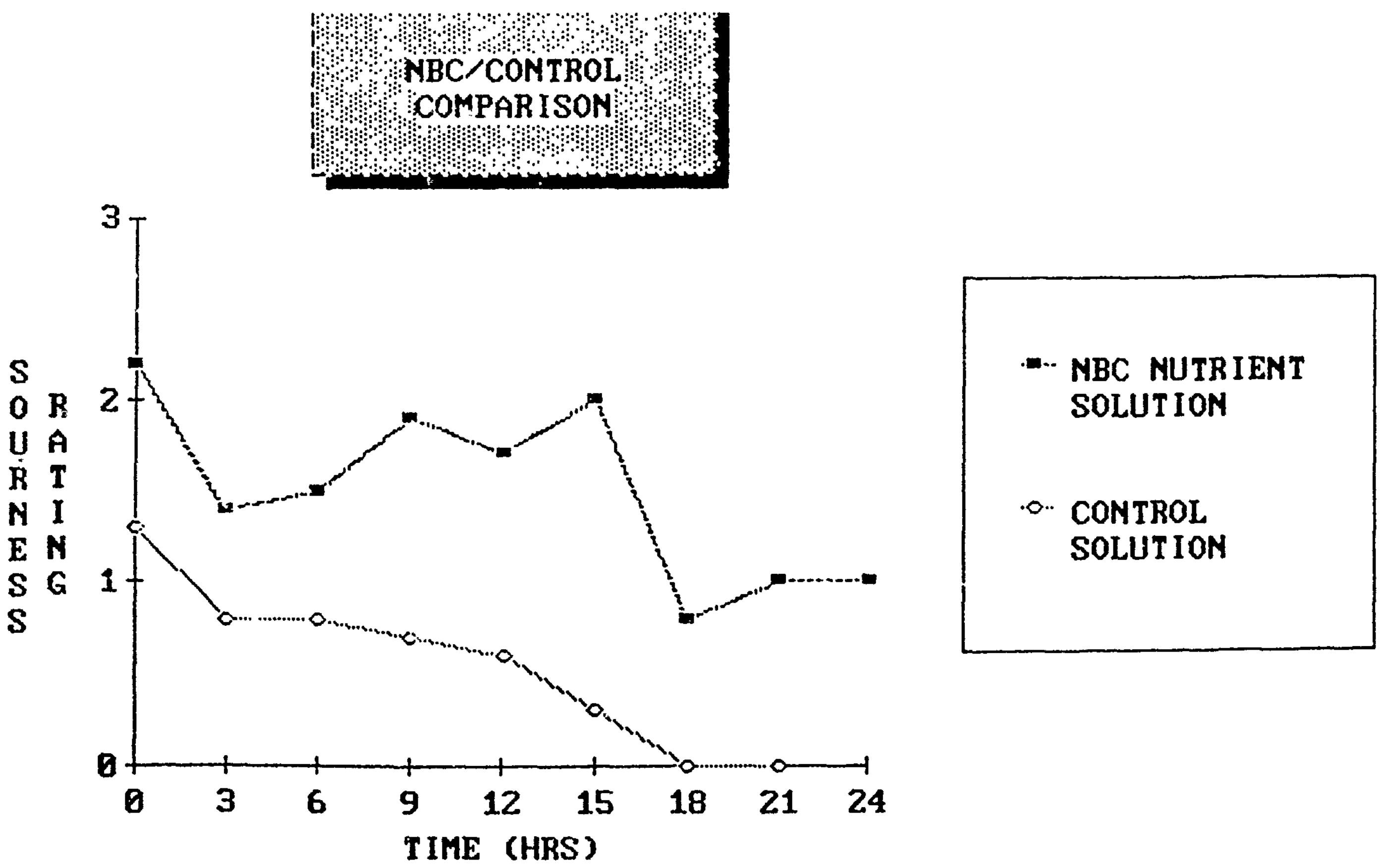


Figure 10. Perceived sourness ratings as a function of time.

INTEGRATED SUMMARY

Fasting and exercise can decrease the performance of a person attempting to work for extended periods in the heat (1-4). Fasting decreases physical (1-5) and mental (1,6,7) performance by lowering blood glucose levels, depleting muscle glycogen stores, altering body fluid homeostasis, etc. Increased heart rates (3), nausea, and side pain (1) are other symptoms of prolonged fasting. Prolonged severe exercise in the heat can lead to hyperthermia (8,9), blood electrolyte imbalances (10), hypoglycemia (11,12), and depletion of muscle glycogen (13,14). Hypohydration is a major factor affecting performance and recovery from exercise (15-17). Loss of more than 2% body weight due to dehydration can decrease plasma volume, increase osmolality, decrease stroke volume and cardiac output, increase heart rate, increase core temperature, reduce sweat rate, and reduce cutaneous blood flow (16,18-24). These physiological alterations can be dangerous for men fasting and exercising in the heat.

Soldiers in MOPP4 ensemble are vulnerable to all of the above problems. They are prone to the effects of fasting because they cannot eat in MOPP4 configuration unless they can find a decontaminated area and uncontaminated food. If a soldier can safely remove the MOPP4 ensemble every few hours, then eating is not a problem and a nutrient solution is not needed. However, scenarios for Nuclear, Biological, and Chemical (NBC) warfare include the possibility of 24-hour contamination which would preclude removal of the ensemble. Wearing the MOPP4 ensemble subjects a soldier to added heat stress. The ensemble does not allow for free heat transfer so the

temperature inside the ensemble is approximately 10 degrees hotter than the ambient temperature (25). If it is possible for the soldier to remain inactive while in MOPP4, then there would be fewer problems with heat stress and dehydration. The soldier would only need a source of water to prevent dehydration and would draw on his body stores to meet his energy needs for the 24-hour period. However, soldiers who are in a contaminated environment would normally be engaged in some type of survival or combat activity. A very active person would dehydrate and deplete body energy stores faster than an inactive person and his ability to perform physical activity would be jeopardized.

A NRC advisory committee (1) recommended a nutrient solution for soldiers encapsulated in MOPP4 for 24 hours, engaged in moderate activity (300 watt workload), sweating about 0.5 liter/hour, and working where the WBGT was about 21°C (70°F). The solution should contain carbohydrate to prevent hypoglycemia and ketosis. Sodium was included in the solution to replace about half the amount that would be lost at this rate of sweating.

In the present study the subjects exercised at approximately 400 watts (29% $\dot{V}O_2max$); were dressed in running shoes and shorts; exercised in a climatic chamber maintained at 98°F, 20% rh, and 2 mph wind speed; and were forced to drink fluids to replace weight lost from sweating. This study was conducted in MOPP0 to separate out the effects of the NBC Nutrient solution from the complications of wearing MOPP4 such as waste elimination, sleep deprivation, face itch, etc. Because the soldiers were in MOPP0, the environmental conditions and exercise rate were changed to simulate the thermal stress of MOPP4. Although the study was designed for 24 hours, the

mean endurance time was 17.1 hours for the NBC Nucrient solution t·is i 16.0 hours for the control solution trial. This study could not prov . conclusive data after the 12th hour because of the decrease in t.. numbe. . subjects who were able to continue participation.

Under the conditions of this study, water and the NBC Nutrient solution were equally effective for the first 12 hours in maintaining hydration, heart rate, core temperature, skin temperature, vigilance, cognitive performance, and motor performance. The results of this study supported previous findings (9,16-24,26) that the amount of fluid ingested rather than the composition of the fluid was the important factor in maintaining body temperature and associated physiological processes during exercise in the heat. The results also confirmed that there were no psychometric changes (1) in the first 12 hours of fasting. The data upheld the recommendations of the NRC committee that water would be sufficient for the first 6 hours without a significant degradation in physiological and psychological performance during light activity at a WBGT of 21°C (70°F). Furthermore, the study provided evidence that water could be sufficient for up to 12 hours if a meal had been eaten prior to encapsulation.

The carbohydrate in the NBC Nutrient solution did cause the blood glucose levels to be higher ($p<0.05$) than for the control solution. This difference was not important for the first 12 hours since the blood glucose levels for the control solution trial did not reach hypoglycemic levels. The higher blood glucose levels might have been important if the subjects had been able to finish 24 hours of testing because the levels for the control trial were decreasing toward hypoglycemic levels. Since glucose is the primary fuel for

the brain, low blood glucose can cause symptoms which might impair mental function (1,6,7). Although the differences between the two solutions were not significant (NS), the NBC Nutrient solution prevented the appearance of ketones for up to 24 hours for all but two subjects. Ketones generally appeared in the urine about 12 hours into the study during the control solution trial. The effects of hypoglycemia and ketosis could not be examined in this study because the subjects could not finish 24 hours of testing. The reasons for terminating participation in the present study would not be applicable to a combat situation because soldiers would not suffer from chafing from a rectal probe or blisters from walking more than 20 miles. Although conclusive evidence is not available from this study, it is possible to speculate that the NBC Nutrient solution may have been more effective than water for the 12-24 hour time period.

The subjects in the present study were exercising at 29% $\dot{V}O_2max$ which probably did not deplete body glycogen stores. At such a low exercise intensity, fat stores are usually the major source of energy rather than the glycogen stores. The data on blood free fatty acids and respiratory exchange ratios provided evidence that the subjects were relying heavily on fat for energy during the control solution trial. During the NBC Nutrient solution trial the subjects were probably utilizing the carbohydrate from the solution for energy. If the soldiers had been subjected to more intense activity, then differences between the two solutions might have been more apparent on the tests. However, the NBC Nutrient solution was formulated for soldiers engaged in moderate activity because the NRC committee recognized that any nutrient solution would be ineffective in counteracting the heat stress associated with heavy activity.

Providing glucose in dilute concentrations prevents a hyperosmolar effect and allows for maximal fluid delivery to the body to prevent gastro-intestinal disturbances and dehydration. The formulation of the NBC Nutrient solution is excellent because it balances nutrients and fluid to prevent the gastro-intestinal disturbances and dehydration. Solid food would preclude these problems. However, carrying around and/or obtaining sufficient amounts of the premixed NBC Nutrient solution or solid food could cause logistical problems. A concentrated liquid nutrient solution that would contain a day's worth of nutrients in one small squeeze package would solve the logistical problems. The soldier would eat a small amount of the concentrated nutrients and would drink water from his canteen. Providing a concentrated hyperosmolar solution could cause problems if sufficient fluids were not available and consumed in a timely fashion to dilute the concentrated nutrients. Any method of providing nutrients to a soldier in MOPP4 would cause some logistical and operational problems but every effort should be made to provide nutrients to the soldier to prolong his ability to work.

The NBC Nutrient solution was effective in improving mood and lessening symptom intensity after 6 hours of exercise in the heat. The subjects did not seem to be indiscriminately reporting higher levels of symptomatology and mood distress in the control trial. There were no significant differences between the two solutions and over time on cognitive, motor performance, and vigilance tests under the conditions of this study. The subjects generally performed better on the psychological tests while drinking the NBC Nutrient solution but no conclusions could be drawn because of the small number of subjects that continued on to the 18th and 24th hours. The difference

between the two solutions might not have been noticeable because the subjects were dropping out of the study prior to the onset of hypoglycemia and just as ketosis was developing.

The NBC Nutrient solution tended to be more acceptable ($p<0.01$) and the subjects consumed more of this fluid even though the difference was not significant. Previous research showed that subjects tended to voluntarily dehydrate when allowed to drink ad libitum (16,27). The higher acceptability ratings of the NBC Nutrient solution might improve fluid intake over that of water and therefore the ability to maintain hydration in soldiers who are not being forced to drink.

The delay in appearance of ketones, higher blood glucose levels, improvement in mood, decrease in symptom intensity, higher acceptability ratings, and the tendency for better performance on the vigilance, cognitive and motor performance tests indicated that the NBC Nutrient solution was of some benefit to the soldier. However, the results of this study did not indicate a clear superiority of the NBC Nutrient solution over plain water when consumed in amounts adequate to replace fluid loss. This study showed that under conditions of forced fluid consumption, water would be sufficient for 12 hours. This study did not provide reliable data for the time period after 17 hours and was not designed to determine the effects of ad libitum consumption of fluids. These conditions should be tested in a study specifically designed to evaluate long term ad libitum consumption of the NBC Nutrient solution during prolonged work in the heat.

The present study was not designed to address the issue of whether the NBC Nutrient solution might be more effective than water in maintaining the

physiological and psychological status of a soldier encapsulated in MOPP4. This study was designed for the subjects to exercise in MOPP0 in order to compare the NBC Nutrient solution to water without waste elimination, sleep deprivation, face itch, etc. interfering with the data. As discussed in the section on Self-Reported Symptoms and Mood, it would be difficult to generalize to soldiers encapsulated in MOPP4 from soldiers in running shoes and shorts because they did not experience all the same problems. This study was not designed to answer questions about the effects of encapsulation in MOPP4 on physiological and psychological tests. This study was designed to determine if the contents of the NBC Nutrient solution would enhance performance compared to water and it showed that when water was forced, water was as effective as the NBC Nutrient solution for the first 12 hours.

REFERENCES

1. Henschel A, Taylor HL, Keys A. Performance capacity in acute starvation with hard work. J Appl Physiol 1954;6:624-633.

2. Taylor HL, Henschel A, Mickelsen O, Keys A. Some effects of acute starvation with hard work on body weight, body fluids and metabolism. J Appl Physiol 1954;6:613-623.

3. Consolazio CF, Nelson RA, Johnson HL, Matoush LO, Krzywicki HJ, Issac GJ. Metabolic aspects of acute starvation in normal humans: Performance and cardiovascular evaluation function. (Laboratory Report No. 298) Denver, CO: US Army Med Res Nut Lab, 1966.

4. Lategola MT. The effect of 5-day, complete starvation on cardiopulmonary functions of aerobic work capacity and orthostatic tolerance. Fed Proc 1965;24:590.

5. Taylor HL, Brozek J, Henschel A, Mickelsen O, Keys A. The effect of successive fasts on the ability of men to withstand fasting during hard work. Am J Physiol 1945;143:148-155.

6. Guetzkow H, Taylor HL, Brozek J, Keys A. Relationship of speed of motor reaction to blood sugar level during acute starvation in man, abstracted. Fed Proc 1945;4:28.

7. Kety SS. The general metabolism of the brain in vivo. In: Richter D, ed. Metabolism of the nervous system. New York: Pergamon Press, 1957: 221-237.

8. Maron MB, Wagner JA, Horvath SM. Thermoregulatory responses during competitive marathon running. J Appl Physiol 1977;42:909-914.

9. Costill DL, Kammer WF, Fisher A. Fluid ingestion during distance running. Arch Environ Health 1970;21:520-525.

10. Frizzell RT, Lang GH, Lowance DC, Lathan SR. Hyponatremia and ultramarathon running. JAMA 1986;255:772-774.

11. Pirnay F, Lacroix M, Mosora F, Luyckx A, Lefebvre P. Effect of glucose ingestion on energy substrate utilization during prolonged muscular exercise. Eur J Applied Physiol 1977;36:247-254.

12. Costill DL, Bennett A, Branam G, Eddy D. Glucose ingestion at rest and during prolonged exercise. J Appl Physiol 1973;34:764-769.

13. Karlsson J, Saltin B. Diet, muscle glycogen, and endurance performance. J Appl Physiol 1971;31:203-206.

14. Ahlborg B, Bergstrom J, Ekelund LG, Hultman E. Muscle glycogen and muscle electrolytes during prolonged physical exercise. Acta Physiol Scand 1967;70:129-142.

15. Williams MH. Nutritional aspects of human physical and athletic performance. Springfield, IL: Charles C. Thomas Publisher, 1976:44-75 and 169-207.

16. Strydom NB, Wyndham CH, van Graan CH, Holdsworth LD, Morrison JF. The influence of water restriction on the performance of men during a prolonged march. So Afr Medical J 1966;31:539-544.

17. Macaraeg PVJ Jr. Influence of carbohydrate electrolyte ingestion on running endurance. In: Fox EL, ed. Report of the Ross symposium on nutrient utilization during exercise. Columbus, OH: Ross Laboratories, 1983:91-96.

18. Pitts GC, Johnson RE, Consolazio FC. Work in the heat as affected by intake of water, salt and glucose. Am J Physiol 1944;142:253-259.

19. Ladell WSS. The effects of water and salt intake upon the performance of men working in hot and humid environments. J Physiol 1955;127:11-46.

20. Adolph EF, Brown AH, Goddard DR, Gosselin RE, Kelly JJ, Molnar GW, Rahn H, Rothstein A, Towbin EJ, Wills JH, Wold AV. In: Physiology of man in the desert. New York: Interscience Publishers, 1947.

21. Wyndham CH. Heat stroke and hyperthermia in marathon runners. In: Milvy P, ed. The marathon: Physiological, medical, epidemiological, and psychological studies. New York: New York Academy of Sciences, 1977: 128-138.

22. Keys A, Brozek J, Henschel A, Mickelsen O, Taylor HL. Human starvation. U. of Minn Press, 1951.

23. Consolazio CF, Johnson RE, Pecora LJ. Physiological measurements of metabolic function in man. New York: Blakiston Division, McGraw-Hill Book Co., 1963.

24. Saltin B. Aerobic and anaerobic work capacity after dehydration. J Appl Physiol 1964;19:1114-1118.

25. Conclusions and recommendations arising from a workshop, held June 3-4, 1982, to determine nutritional requirements of military personnel in protective clothing, Committee on Nutritional Requirements in Protective Clothing, Food and Nutrition Board, Commission on Life Sciences, National Research Council.

26. Kenney RA. The effect of the drinking pattern on water economy in hot, humid environments. Brit J Industr Med 1954;11:38-39.

27. Kerndt PR, Naughton JL, Driscoll CE, Loxterkamp DA. Fasting: The history, pathophysiology and complications. West J Med 1982;137:379-399.

GENERAL CONCLUSIONS

The results of this study generally suggest that provision of the NBC Nutrient solution as a hydrating beverage for work in the heat provides little advantage over water during the first 12 hours of fasting. These results are based on soldiers working at about 400 watts (29% $\dot{V}O_2max$), at a WBGT of 21°C (70°F), sweating at 0.5 liters/hour, and consuming a light meal prior to the start of the fast. This study showed that soldiers could perform their duties effectively for up to 12 hours while drinking water alone, however, providing the NBC Nutrient solution significantly improved mood and lowered self-reported symptom intensity after 6 hours. This study was designed to examine the effects of the NBC Nutrient solution for 24 hours but conclusions for the period from 12-24 hours were unreliable because too many subjects were dropping out of the study because of extraneous problems such as foot blisters.

PHYSIOLOGICAL:

1. Fluid balance and body weight data showed that the subjects were fairly well hydrated but some weight loss did occur (1.35% NBC, 1.98% control).
2. Both solutions were effective in maintaining hydration as indicated by the clinical chemistries. Statistically significant differences were found in several variables, however most differences remained in the clinically normal range.
3. The NBC Nutrient solution provided no thermoregulatory or cardiovascular advantage over the control solution. There were no significant differences

between the two solutions for rectal temperature, skin temperature, heart rate, metabolic rate, and sweating rate.

4. The difference in endurance time for the two solutions was not significant.

5. The blood glucose levels for the NBC Nutrient solution trial were significantly higher. However, blood glucose levels for both solutions remained within normal physiological levels.

6. The NBC Nutrient solution delayed the appearance of urinary ketones compared to the control solution but the difference was not statistically significant.

PSYCHOLOGICAL:

7. After 6 hours, the subjects drinking the NBC Nutrient solution experienced significantly lower symptom intensity and improved mood.

8. The acceptability of the NBC Nutrient solution was significantly higher than the control solution. Preference for both solutions decreased significantly over time.

9. Performance on the cognitive, motor, and vigilance tests was not significantly different between the two solutions.

RECOMMENDATIONS

The following recommendations are based on data collected from twelve subjects (data from subject #6 were excluded from some of the tests) who were working at 400 watts and sweating at 0.5 liters/hour. The subjects were not encapsulated in any MOPP ensemble but the environmental conditions were controlled to simulate the thermal stress of MOPP4 at a WBGT of 21°C (70°F). The study was designed to test two solutions for 24 hours but mean endurance time was 17.1 hours for the NBC Nutrient solution and 16.0 hours for the control solution (colored and flavored water). Therefore, these recommendations should be interpreted carefully because the results of this test were equivocable after the first 12 hours.

1. Further exercise-heat scenario laboratory studies testing the NBC solution for the first 12 hours of fasting are not recommended since the results of this study indicate that water is as effective as the NBC Nutrient solution in maintaining physiological and psychological performance during that period of time.
2. Recommend a study to test the acceptability of the NBC Nutrient solution in a MOPPO hot field training environment. The acceptance ratings indicated that the NBC Nutrient solution was preferred over the control solution and thus a higher voluntary consumption rate of the NBC Nutrient solution might be predicted.
3. If the NBC Nutrient solution is more acceptable than water, then a study of the effects of <u>ad libitum</u> ingestion of the NBC Nutrient solution on

physiological and psychological indices in a simulation of the thermal stress of MOPP4 would be recommended. The design of the present study precluded examination of the effect of the NBC Nutrient solution on voluntary hydration. Under the theoretical situation of an increased acceptability and consumption rate of the NBC Nutrient solution, the significant differences noted in the present study (higher blood glucose, lower ketones, lowered symptom intensity, and improved mood) might combine to enhance certain aspects of psychological and physical performance.

4. A study to compare the effects of the NBC Nutrient solution to water when ketosis has developed and blood glucose levels are dropping is recommended. This study should be conducted under conditions that simulate the thermal stress of the MOPP4 configuration but excludes the complications of wearing the MOPP ensemble.

5. Testing should be conducted on other nutritional products which might aid the soldier in the field. A possible alternative to the NBC Nutrient solution might be a tube of concentrated nutrients which would replenish glycogen and electrolyte losses. The liquid nutrients would be ingested in small frequent doses during the day so as not to cause hyperosmolar problems. Water from the canteen would be used for fluid replacement.

6. If any of the above tests in MOPP0 show that the NBC Nutrient solution is more effective than water in maintaining physiological and psychological indices, then a study in MOPP4 is recommended. This study should determine whether all the interacting variables of MOPP4 configuration would enhance or suppress the effectiveness of the NBC Nutrient solution.

7. Based on the results of this study, the formulation for the NBC Nutrient solution does not need to be changea. However, the literature suggests that glucose polymers would be a better source of glucose. The subjects did not report problems with the NBC Nutrient solution but fructose has been associated with gastro-intestinal distress.

APPENDICES

APPENDIX 1

APPENDIX 1

CONCLUSIONS AND RECOMMENDATIONS ARISING FROM A WORKSHOP, HELD JUNE 3-4, 1982, TO DETERMINE NUTRITIONAL REQUIREMENTS OF MILITARY PERSONNEL IN PROTECTIVE CLOTHING

Committee on Nutritional Requirements in Protective Clothing
Food and Nutrition Board
Commission on Life Sciences
National Research Council

The Committee on Nutritional Requirements in Protective Clothing was established to recommend nutrient solutions that would be most suitable to sustain military personnel who had responded to a nuclear, biological, or chemical attack by putting on protective clothing. It is assumed that such solutions would be ingested through a gas mask drinking tube. The solutions recommended below are not designed to meet ongoing nutrient needs but, rather, to allow the individual to function for 6 to 24 hours, drawing primarily on existing body nutrient stores. They would not provide optimal or even desirable levels of nutrients for repeated, consecutive 24-hour periods. However, the Committee intends that the suggested formulation should not only meet the minimum requirements for survival, but also be sufficient to maintain the highest practicable level of mental and physical performance of the troops wearing the protective gear. Because the adoption of the Committee's recommendations will result in a negative balance for many nutrients over the 24-hour period, it is desirable that the personnel be returned to normal military rations as soon as practicable. The Committee recognizes that high environmental temperatures and/or a heavy workload may still produce heat illness despite achievable rehydration and/or electrolyte replacement.

The Committee members are in agreement that a suitable nutrient solution must counter losses of certain nutrients, primarily water and electrolytes. For periods of 24 hours or less, however, they see no need to supply protein, amino acids, fat, fatty acids, or micronutrients, i.e., iron, zinc, copper, manganese, trace minerals, or vitamins.

It is not necessary to supply calories during the first 6 hours, but they should be provided thereafter. Although carbohydrates need not be the sole or principal source of these calories, they do have certain advantages: they eliminate ketosis, counteract continuous hypoglycemia, are palatable, and do not obligate urinary water loss. In contrast, fat is inadvisable because it is ketogenic and delays gastric emptying. Another possible source is amino acids, but they have a drawback in that they induce increased urinary water loss because of the conversion of their nitrogen moiety to urea. By exclusion, therefore, carbohydrates should be the main source of calories.

For individuals performing sedentary work in a temperate environment, e.g., 15.6°C (60°F WBGT[1]) but wearing protective clothing--which is equivalent to adding 6°C (10°F)--the Committee recommends that access to 1 liter[2] of water be provided during the first 6 hours and that an additional liter should be accessible over the ensuing 18 hours. This recommendation follows the still valid work of Adolph (1947)[3] and is consistent with current Army policy. Because the work is sedentary and the environment temperate, consumption of this amount of water is not mandatory but is desirable.

In a "worst case" situation, i.e., a WBGT of 27°C (80°F)-- which is roughly equivalent to 33°C (90°F) because of the protective clothing--and

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1 WBGT=Wet bulb globe temperature.

2 Volumes specified as liters are approximate. The provision of 1 U.S. quart (i.e., one full canteen) in lieu of each liter specified is considered an adequate equivalent to one liter.

3 Adolph, E.F. 1947. Physiology of Man in the Desert. Interscience Publishers, New York, 347 pp.

a heavy workload of 500 Watts (450 kcal/hour), studies have shown that casualties from heat-related disorders will reach approximately 50% within 1 hour. This casualty rate cannot be reduced by any replacement solution, however formulated, because performance of individuals wearing protective clothing of current design, under such conditions, is limited by heat stress that cannot be counteracted by water or other nutrient replacement.

In an intermediate situation, i.e., a moderate workload of 300 Watts (250 kcal/hour) performed in a WBGT of 21°C (70°F), water loss for wearers of protective gear will be approximately 3 liters during the first 6 hours.[4] In the ensuing 18 hours of continued activity at the same work rate, an additional 9 liters will be lost. For the first 6 hours, the water in the two routinely carried canteens will suffice as the replacement solution, and at least both canteens should be consumed.[5] A nutrient solution, made available after the first 6 hours, should be consumed at a rate of 2 liters per 6-hour period, i.e., a total of 6 additional liters in the ensuing 18 hours. Each 6 liters of this solution should contain a minimum of 500 kcal and should approach a maximum of 250 mEq sodium (Na^+) and 225 mEq chloride (Cl^-), i.e., approximately 42 mEq Na^+ and 38 mEq Cl^- per liter since the concentration of sodium in sweat is related to the chloride concentration,[6]

[4] Actual losses will vary depending upon several factors including individual body weight

[5] The Committee recognized that dehydration exceeding approximately 5% of total body weight could seriously decrease the operational performance of personnel; however, continuance of normal urine output could compromise the protection afforded by the garment against chemical agents. Hence, the Committee recommends replacing approximately two-thirds of liquid losses.

[6] Robinson, S. 1954. Chemical composition of sweat. Physiol. Rev. 34: 202-219.

i.e., $[Na^+] = 1.12 [Cl^-] + 3$ mEq. This maximum is based on a 24-hour sweat loss of approximately 500 mEq Na^+ and a 50% replacement. Losses will range between means of approximately 25 and 75 mEq Na^+/liter sweat, depending upon previous diet, acclimatization, and other factors. When WBGT exceeds 21°C (70°F) and/or workload exceeds 150 kcal/hour, more than 2 liters of this solution should be consumed during each 6-hour period.

- The fluid should not exceed 310 mosmol/liter to ensure palatability and efficient gastric emptying. However, the above-noted requirements could be met with a solution of approximately 150 mosmol/liter, which the Committee recommends because such a formulation would provide more free water to the dehydrated personnel. Since the Na^+ and Cl^- provide about 80 mosmol/liter, approximately 70 mosmol/liter (shelf-osmolarity) should be provided as carbohydrate such as glucose and/or sucrose and/or digestible glucose polymers.

It is not necessary that the solution provide magnesium, phosphorus, or calcium. Because of the dehydration and low urine output, the Committee does not recommend that potassium be provided in the solution as a nutrient. Inclusion of potassium and phosphorus (as phosphate) for nonnutrient purposes is discussed below.

When formulating such solutions, any additions of preservatives, or other materials must meet the above guidelines. The inclusion of potassium is not precluded, but its presence should not exceed 3 mEq/liter. Phosphate should not exceed 5 mEq/liter. There is reason for concern about adding potassium and phosphate: the personnel will be in negative caloric balance and working resulting in the mobilization of potassium and phosphate from storage. As dehydration progresses, urine output decreases. Consequently, the plasma concentrations of these elements are not reduced[7].

As a first step in evaluation of these recommendations, the Army medical staff should consider the extent to which the resultant upper level of dehydration (approximately 5% at the end of 24 hours) is likely to influence operational effectiveness. To evaluate its benefits to operational effectiveness, the effects of the specific formulation recommended here should then be compared to: (1) no liquid; (2) water alone; and (3) a closed system complete diet,[8] given to both acclimatized and nonacclimatized volunteers in a climatic chamber/laboratory. Similar comparisons should also be conducted under field conditions.

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7 Knochel, J.P., L.N. Dotin, and R.J. Hamburger. 1972. Pathophysiology of intense physical conditioning in a hot climate. I. The mechanisms of potassium depletion. J. Clin. Invest. 51: 242-245; Knochel, J.P., and E.M. Schlein. 1972. On the mechanism of rhabdomyolysis and potassium depletion. J. Clin. Invest, 51:1750-1758; and Knochel, J.P. 1974. Environmental heat illness. Arch. Int. Med. 133:841-864.

8 The closed-system complete diet should provide the Recommended Dietary Allowance for all essential nutrients, and could resemble the complete liquid formula diets in current clinical use.

APPENDIX 2

NBC NUTRIENT SOLUTION POWDER FORMULA

INGREDIENTS	g/l	g/qt
Malti Dextrin-42	10.3960	9.8075
Fructose	14.4372	13.6200
Aspartame	0.1060	0.1000
Salt	1.3250	1.2500
Citric acid	2.6500	2.5000
Tricalcium phosphate	0.3890	0.3670
Sodium benzoate	0.2120	0.2000
LL Flavor Fries & Fries 88481	0.0636	0.0600
LL Flavor Fries & Fries 88484	0.0424	0.0400
LL Flavor Fries & Fries 80523	0.0530	0.0500
FDC Yellow color #5	0.0016	0.0015
Lime shade McCormick C00266	0.0042	0.0040
Total grams	29.6800	28.0000

Per 6 liters:
562 kcal
2.34% CHO (148.8 g CHO)
145 mEq Na^+

Per 1 liter:
93.7 kcal
2.34% CHO (24.8 g CHO)
24.1 mEq Na^+

Osmolality - 154-177 mOsm/kg

CONTROL SOLUTION

	g/l	g/qt
LL Flavor Fries & Fries 88481	0.0636	0.0600
LL Flavor Fries & Fries 88484	0.0424	0.0400
LL Flavor Fries & Fries 80523	0.0530	0.0500
FDC Yellow color #5	0.0016	0.0015
Lime shade McCormick C00266	0.0042	0.0040

APPENDIX 3

NBC NUTRIENT SOLUTION SCHEDULE
WEEK I

PHASE I -->

MONDAY 9 Mar	TUESDAY 10 Mar	WEDNESDAY 11 Mar	THURSDAY 12 Mar	FRIDAY 13 Mar
0715 hrs Subjects Report	0715 hrs Subjects Report	0715 hrs Subjects Report	0715 hrs Subjects Report	0715 hrs Subjects Report
0800-1000 hrs TCR Acclimate FASS (15 min)	0800-1000 hrs TWT FASS (5 min) Acclimate FASS (5 min)	0800-1000 hrs TCR FASS (5 min) Acclimate FASS (5 min)	0800-1000 hrs TWT FASS (5 min) Acclimate FASS (5 min)	0800-1000 hrs TCR FASS (5 min) Acclimate FASS (5 min)
1030-1200 hrs ACR CAMP (60 min)	1030-1200 hrs ACR CAMP (60 min)	1030-1200 hrs ACR CAMP (60 min) Vigilance (30 min)	1030-1200 hrs ACR CAMP (60 min) Vigilance (30 min)	1030-1200 hrs ACR CAMP (60 min) Vigilance (30 min)
1300-1430 hrs ACR CAMP	1300-1430 hrs ACR CAMP	1300-1430 hrs ACR CAMP (60 min) Vigilance (30 min)	1300-1430 hrs ACR CAMP (60 min) Vigilance (30 min)	1300-1430 hrs ACR CAMP (60 min) Vigilance (30 min)
1430-1630 hrs USARIEM Exercise	1430-1630 hrs USARIEM Exercise	1430-1630 hrs USARIEM Exercise	1430-1630 hrs USARIEM Exercise	1430-1630 hrs USARIEM Exercise

ACR=Arctic Conditioning Room
TCR=Tropic Conditioning Room
TWT=Tropic Wind Tunnel

FASS=Food Acceptance and Subjective Self-Reports
CAMP=Cognitive And Motor Performance tests
Mood=Self-Reported Symptoms and Mood States

NBC NUTRIENT SOLUTION SCHEDULE
WEEK II

PHASE I ——>			PHASE II ——>	PHASE III ——>
MONDAY 16 Mar	TUESDAY 17 Mar	WEDNESDAY 18 Mar	THURSDAY 19 Mar	FRIDAY 20 Mar
0715 hrs Subjects Report	0715 hrs Subjects Report			
0800-1000 hrs TCR FASS (5 min) Acclimate FASS (5 min)	0800-1000 hrs TWT FASS (5 min) Acclimate FASS (5 min)		0600-2400 hrs TWT 24 HR TEST	0001-0800 hrs TWT 24 HR TEST
				0800-0900 HRS Mood
				0900-1000 hrs Recovery
	1000-1100 hr CAMP TWT 1100-1200 hr Mood TWT	1000-1400 HR EXERCISE TEST USARIEM		1000-1400 hr EXERCISE TEST USARIEM
1300-1600 hrs USARIEM Hydrostatic Weigh Max Aerobic Test	1300-1600 hrs USARIEM Hydrostatic Weigh Max Aerobic Test	1400 hrs Heat Casualty Lecture LCR. USARIEM		

ACR=Arctic Conditioning Room
TCR=Tropic Conditioning Room
TWT=Tropic Wind Tunnel
LCR=Large Conference Room

FASS=Food Acceptance and Subjective Self-Reports
CAMP=Cognitive And Motor Performance tests
Mood=Self-Reported Symptoms and Mood States

NBC NUTRIENT SOLUTION SCHEDULE
WEEK III

PHASE III ------------------------------------> PHASE IV ----->

MONDAY 23 Mar	TUESDAY 24 Mar	WEDNESDAY 25 Mar	THURSDAY 26 Mar	FRIDAY 27 Mar
0715 hrs Subjects Report	0715 hrs Subjects Report			
0800-1000 hrs TWT FASS (5 min) Acclimate FASS (5 min)	0800-1000 hrs TWT FASS (5 min) Acclimate FASS (5 min)		0600-2400 hrs TWT 24 HR TEST	0001-0600 hrs TWT 24 HR TEST 0800-0900 HRS Mood 0900-1000 hrs Recovery
	1000-1100 hrs CAMP TWT 1100-1200 hrs Mood TWT	1000-1400 HR EXERCISE TEST USARIEM		1000-1400 hr EXERCISE TEST USARIEM

ACR=Arctic Conditioning Room
TCR=Tropic Conditioning Room
TWT=Tropic Wind Tunnel

FASS=Food Acceptance and Subjective Self-Reports
CAMP=Cognitive And Motor Performance tests
Mood=Self-Reported Symptoms and Mood States

APPENDIX 4

24-HR HEAT TEST SCHEDULE

Study day	
0545	Collect urine as soon as awaken
	8 subjects report to climatic chamber
	Breakfast provided to test subjects
	Change into shorts and sneakers
	Weighed nude
	Skin temperature harness attached
	Rectal temperature probe attached
	Heart Rate Monitor attached
	Catheter inserted
	Pre-test blood drawn after standing 20 min
	Blood PU
0745	Enter Chamber
	Weighed with all equipment
	Hooked up
0750	Stand for 10 minutes
	Canteen received
	Food Acceptance & Subjective Self-Reports (FASS) Testing (2 Min)
0800	Start Treadmill walking/drink
0830	Metabolic Bag
0845	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
0855	Cognitive & Motor P ormance (CAMP) testing/no drinking
0910	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
0925	Hooked up
	Urine Pick up
0930	Start Treadmill/Drink
0945	Stop Drinking
1000	Blood Drawn
	Blood PU
1015	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
1025	CAMP testing/no drinking
1040	FASS testing/Drink
	Receive new canteen
1042	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
1055	Hooked up
	Urine pick up
1100	Start Treadmill/Drink
1130	Metabolic Bag
1145	Stop Treadmill
	Weighed w/all equipment/Fluid recorded

1155	CAMP Testing/no drinking
1210	Mood Questionnaire/No Drinking
1225	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
1225	Hooked up
	Urine pick up
1230	Start Treadmill/Drink
1245	Stop Drinking
1300	Blood Drawn for Hydrational & Nutritional Assessment
	Blood PU
1315	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
1325	Vigilance testing/no drinking
1350	FASS testing/Drink
	Receive canteen
1352	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
1355	Hooked up
	Urine pick up
1400	Start Treadmill/Drink
	Metabolic Bag
1445	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
1455	CAMP testing/no drinking
1510	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
1525	Hooked up
	Urine pick up
1530	Start Treadmill/Drink
1545	Stop Drinking
1600	Blood Drawn
	Blood PU
1615	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
1625	CAMP testing/no drinking
1640	FASS testing/Drink
	Receive canteen
1642	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
1655	Hooked up
	Urine pick up
1700	Start Treadmill/Drink
1730	Metabolic Bag
1745	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
1755	CAMP testing/no drinking
1810	Mood Questionnaire/No Drinking

1825	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
	Hooked up
	Urine pick up
1830	Start Treadmill/Drink
1845	Stop drinking
1900	Blood Drawn for Hydrational and Nutritional Assessment
	Blood PU
1915	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
1925	Vigilance testing/no drinking
1950	FASS questionnaire/Drink
	Receive canteen
1952	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
1955	Hooked up
	Urine Pick Up
2000	Start Treadmill/Drink
2030	Metabolic Bag
2045	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
2055	CAMP testing/no drinking
2110	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
2125	Hooked up
	Urine Pick Up
2130	Start Treadmill/Drink
2145	Stop Drinking
2200	Blood Drawn
	Blood PU
2215	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
2225	CAMP testing/no drinking
2240	FASS testing/Drink
	Receive canteen
2242	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
2255	Hooked up
	Urine Pick Up
2300	Start Treadmill/Drink
2330	Metabolic Bag
2345	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
2355	CAMP testing/no drinking
0010	Mood Questionnaire/No Drinking
0025	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded

0025	Hooked up
	Urine Pick Up
0030	Start Treadmill/Drink
0045	Stop Drinking
0100	Blood Drawn for Hydrational and Nutritional Assessment
	Blood PU
0115	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
0125	Vigilance Testing/no drinking
0150	FASS questionnaire/Drink
	Receive canteen
0152	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
0155	Hooked up
	Urine Pick Up
0200	Start Treadmill/Drink
0230	Metabolic Bag
0245	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
0255	CAMP testing/no drinking
0310	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
0325	Hooked up
	Urine Pick Up
0330	Start Treadmill/Drink
0345	Stop Drinking
0400	Blood Drawn
	Blood PU
0415	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
0425	CAMP testing/no drinking
0440	FASS testing/Drink
	Receive canteen
0442	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
0455	Hooked up
	Urine Pick Up
0500	Start Treadmill/Drink
0530	Metabolic Bag
0545	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
0555	CAMP testing/no drinking
0610	Mood Questionnaire/No Drinking
0625	Rest/bathroom/drink to make up weight loss/change socks
	Weighed w/all equipment/Fluid recorded
0625	Hooked up
	Urine Pick Up

0630	Start Treadmill/Drink
0645	Stop Drinking
0700	Blood Drawn for Nutritional and Hydrational Assessment
	Blood PU
0715	Stop Treadmill
	Weighed w/all equipment/Fluid recorded
0725	Vigilance testing/no drinking
0750	FASS questionnaire/Drink
	Receive canteen
0752	Rest/bathroom/drink to make up weight loss
	Weighed
0800	Mood exit interview or as soon as drop out of test
	Urine Pick Up
0900	FINISHED with Heat Stress Test!!!
	EAT!!
1000	Exercise Post Test (if completed 24 hours)
1400	FINISHED!!!!

APPENDIX 5

MEDICAL MONITOR REPORT FOR THE NBC NUTRIENT SOLUTION STUDY.

Test subjects were exposed to heat and humidity stresses for a 24-hour work period, and their physical and mental performances were measured during the 24-hour work period of walking and test taking. During the 24-hour work period, test subjects were given only fluids. The fluids consisted of either a flavored water without nutritional caloric value or an electrolyte solution containing a sugar. Each test subject participated in two different 24-hour work periods, and received the flavored water during one 24-hour work period and the electrolyte and sugar solution during the other 24-hour work period. All 24-hour work periods were preceded by training periods during which the test subjects became physiologically acclimated to the physical work loads and mentally skilled at test taking under the heat and humidity stresses of the study.

All test subjects had received a complete physical examination with medical history and review of systems within a year prior to participation in the study and had had no significant intercurrent illnesses between their last physical exam and the time of the study.

With the exception of one test subject, none of the test subjects had ever experienced heat injury of any degree of severity. Test subject #5 reported that in 1984 he had suffered heat injury which had resulted in a loss of consciousness, and the administration of intravenous solutions with immersion of test subject #5 in an ice bath as part of the resuscitation effort. He has not had a subsequent heat injury despite recurrent exposure to conditions of heat and humidity.

Baseline laboratory studies were done prior to the study and no significant abnormalities were found which would preclude participation in the study. Further medical work up was initiated for significant abnormalities found during review of medical records or as a result of laboratory testing.

During the periods of acclimation, there were no medical problems. These acclimation periods generally lasted about 2 hours.

During the 24-hour work periods, several minor medical problems developed, which contributed to reduced work performance in some cases. However, these medical problems resolved without sequelae over the subsequent 2 - 4 days after the 24-hour work period. Each of these problems will be discussed below under numbered paragraphs.

(1) There was a theoretical concern that hyponatremia would develop would develop in those test subjects who received only flavored water as a fluid replacement without replacement of sodium lost through sweating. Neither significant hyponatremia nor hypokalemia developed in any test subject.

(2) Miliaria (heat rash) developed in about half of the test subjects. Only the lower extremities were involved. This condition resolved completely within two days in all test subjects who developed miliaria.

(3) Blisters on the feet developed in the vast majority of the test subjects during the 24-hour work periods. This is best ascribed to the environmental conditions of the protocol (heat and humidity) and to the work load of

walking for as far as 42 miles during the 24-hour work period. All blisters were treated during the 24 hour work period. A few of the test subjects withdrew from the protocol because of foot blisters. Efforts to reduce the rate of development of foot blisters had been instituted and included such maneuvers as selection of properly fitted and conditioned shoes, frequent change of socks, use of two pairs of socks, use of talc powder, use of Tufskin, air drying the feet during rest periods, regular examination of feet for early detection and treatment of blisters, etc. Despite these efforts, the occurrence of foot blisters did not appear to be significantly reduced. The test subjects were retested with the second fluid one week after completion of the first test period. Most of the blisters had not resolved over the preceding week, and this probably contributed to the shortening of the endurance times during the second 24-hour work period. The order of the fluid administration had been randomized in the protocol to account for these effects. However, a recommendation might be made that the rest period between 24-hour work periods be lengthened or that the work load during the 24-hour work period be changed to not include the same amount of walking (42 miles). Under real conditions, it is unlikely that soldiers would be required to walk 42 miles in a 24-hour time period to escape the effects of NBC agents. For this reason, blisters would probably not be as frequent a problem as they were in the study protocol. On the other hand, in a real situation, frequent 24-hour scenarios are more likely to develop, and on this basis, soldiers would not have a week to recover from blisters as occurred during the study protocol. Nevertheless, 9/11 of the test subjects had a shorter endurance time on the second 24-hour work period no matter what

solution each test subject was drinking. The test subjects who started the study with the NBC solution, had a significantly longer duration time on the NBC solution when compared to the subjects who started on water and then changed to the NBC solution.

(4) Chafing of the skin of the medial thigh and/or perineal area occurred in several of the test subjects and was a reason for the withdrawal from the 24-hour work period. Again, this was related to the heat and humidity conditions of the 24-hour work period as well as the distance walked by the test subjects. Chafing generally occurred in those test subjects with generous medial thighs which were constantly being rubbed by the opposing medial thigh. Use of biking shorts appeared to reduce the rate of development of this complication. This problem resolved without sequelae in all test subjects over the two to four days after each 24-hour work period. It is suspected that chafing would not develop as soon, if at all, in soldiers who were wearing their usual BDU.

(5) Headaches occurred in a number of the test subjects (Table 1). These headaches were not part of an early heat injury syndrome. This assertion is based on the fact that no test subject had a rectal temperature greater than 39.5°C during the 24-hour work period. The headaches did not correlate with the type of fluid ingested, however, a greater number of headaches did occur during the second 24-hour work period for both solutions (Table 2). The headaches were of the tension headache variety. For this reason, the headaches were treated with tylenol and the test subject was permitted to

continue the study. These headaches resolved soon after the tylenol was given, although in some cases, the headache recurred. There were no headaches which persisted after the 24-hour work periods, and there were no other neurological signs or symptoms.

Table 1. Administration of tylenol for headache control, endurance time, and reason for terminating participation.

Subject Number		Tylenol use (# tabs @ hr:min of study completed)	Duration Time[1] (hr:min)	Departure Reason
1	Control	2 tab @ 06:00 2 tab @ 09:00 2 tab @ 13:00	13:30	heat rash
	NBC	2 tab @ 14:45	16:40	chafing rectal probe
2	Control	2 tab @ 04:00 2 tab @ 07:30 2 tab @ 10:20 2 tab @ 09:20	17:50	too tired, exhausted
	NBC	2 tab @ 12:30	24:00	finished 24 hours
3	Control		16:30	chafing between legs, leg cramps
	NBC		13:17	chafing between legs
4	Control	2 tab @ 14:50	16:20	too tired, dehydrated, will not drink
	NBC	2 tab @ 09:20	15:17	foot blisters, heat rash
5	Control		15:40	leg cramps, heat rash
	NBC	2 tab @ 09:20 2 tab @ 14:24	16:10	feet gave out, exhausted URI, weaving on treadmill
6	Control		09:45	URI, sore throat,felt poorly
	NBC		24:00	finished 24 hours

Table 1 (continued)

Subject Number		Tylenol use (# tabs @ hr:min of study completed)	Duration Time[1] (hr:min)	Departure Reason
7	Control		16:15	knees feel sore
	NBC		14:45	sore knees and ankles, chafing
8	Control		09:00	feet hurt
	NBC		15:05	feet hurt
9	Control		16:15	blisters
	NBC	2 tab @ 06:15	14:45	sore knees, blisters
10	Control		16:32	nauseated, light-headed headache
	NBC	2 tab @ 09:00 2 tab @ 15:00	16:10	chafing rectal probe
12	Control		20:35	fatigue
	NBC		24:00	finished 24 hours
13	Control	2 tab @ 09:00	17:48	blisters
	NBC		17:37	blisters

[1]All 24-hour heat stress tests started at 0800 hours.

Table 2. Relationship of tylenol use to type of solution consumed during two 24-hour heat stress trials.

Time of Day	Test Subject	Complaint/Treatment		Fluid Trial
PERIOD OF 12-13 FEB 1987				
2030	2	h/a	2 Tylenol	NBC
2245	1	h/a	2 Tylenol	NBC
2250	4	h/a	2 Tylenol	CONTROL
PERIOD OF 19 - 20 FEB 1987				
1200	2	h/a	2 Tylenol	CONTROL
1400	1	h/a	2 Tylenol	CONTROL
1530	2	h/a	2 Tylenol	CONTROL
1700	1	h/a	2 Tylenol	CONTROL
1820	2	h/a	2 Tylenol	CONTROL
1720	5	h/a	2 Tylenol	NBC
1720	2	h/a	2 Tylenol	CONTROL
1720	4	h/a	2 Tylenol	NBC
2100	1	h/a	2 Tylenol	CONTROL
2224	5	h/a	2 Tylenol	NBC
PERIOD OF 19 - 20 MAR 1987				
NO TYLENOL WAS GIVEN DURING THIS 24-hour work PERIOD				
PERIOD OF 26 - 27 MAR 1987				
1415	9	h/a	2 Tylenol	NBC
1700	10	h/a	2 Tylenol	NBC
1700	13	h/a	2 Tylenol	CONTROL
2300	10	h/a	2 Tylenol	NBC

12 - 13 FEB 1987	1, 2, 6 received NBC Solution
	3, 4, 5 received control solution (colored/flavored water)
19 - 20 FEB 1987	3, 4, 5 received NBC Solution
	1, 2, 6 received control solution
19 - 20 MAR 1987	7, 9, 10 received control solution
	8, 12, 13 received NBC solution
26 - 27 MAR 1987	8, 12, 13 received control solution
	7, 9, 10 received NBC Solution

APPENDIX 6

MUSCLE STRENGTH

METHODS

Isokinetic lift strength was determined with a computer controlled isokinetic lifting dynamometer, the Cybex Liftask ergometer (LE) (Lumex Corp., Ronkonkoma, NY). The subject lifted a bimanual handle from six inches above the floor to the height corresponding to the subject's fullstanding knuckle height. The handle was connected to the LE which provided an accommodating isokinetic resistance to lifting at a speed of 36 inches per second. The computer recorded timing, force, and distance measures during each of the test lifts. From these measures the computer calculated the following variables: A) PKFORCE, the peak force during the lift, measured in pounds. This was the highest force attained during the course of any single lift during a test bout. B) HTPK was the handle height above the lifting platform at which PKFORCE occurred, measured in inches. C) AVEFORCE, this was the average magnitude of the force curve during the repetition of the test set that had the largest area beneath the force-height curve. This repetition is the best work repetition. AVEFORCE was measured in pounds. D) TTLWORK was the total work done during the best work repetition. The best work repetition documented the maximum work performed over the course of the entire lift and as such gave a broader picture of the subject's performance than PKFORCE did. Work was defined as the lifting force multiplied by the distance of the lift. TTLWORK was a representation of work output at the tested speed of 36 inches per second and was measured in foot pounds. E)

AVEPOWER was the average power during the best work repetition. This was calculated by dividing the TTLWORK of the best work repetition by the total time of the best work repetition. This is an index of the intensity of the lifting exercise and is expressed in watts.

The above variables are all related to maximal lifting capacity. This is the type of activity that a soldier may be called upon to perform during times of high stress. An example might be when a soldier is called upon to rescue himself or others from a life threatening situation. Although maximal exertions are infrequent during the daily lives of most soldiers, there are times when physical performance of this nature are critical. Additionally maximal capacity lifting is part of the daily work routine for soldiers such as heavy vehicle mechanics.

The lifting technique used was a "squat" type lift, in which the subjects grasped the handle of the LE in a bent knee, straight back position with their arms extended down between their legs to the handle. The subject executed the lift by standing up and pulling the handle to the fullstanding knuckle height with straight arms. The principle muscle groups involved in this type of lifting maneuver are the quadriceps, gluteus maximus, and the erector spinae. This lift is similar in action to a bent leg dead lift.

The subject's form during lifting was carefully monitored and corrected to meet the standards of the lifting technique. The subject's were encouraged to stretch prior to lifting and as needed during the course of testing. Their warmup was insured by each subject starting their testing regimen by performing a set of four practice lifts. These lifts were executed with proper form but using a self selected submaximal effort. These

lifts were followed within 30 seconds by three maximal effort test lifts. There was a 60 second rest period and then the four practice and three test lifts were repeated. Data was collected during the test repetitions only.

The five days of testing were planned to allow the subjects to stabilize their lifting technique and to assess the day to day reliability of the tests. Subjects were brought in for a sixth day of testing during which they performed two test cycles using the squat technique. This was done to assess the within day reliability of the test.

To determine the effects of the two different fluids on isokinetic lifting strength, subjects were tested on the day prior to each 24-hour heat stress trial. Only those subjects that completed a 24-hour test were post-tested. This was done so that the pre- and post-tests would compare subjects that had completed similar amounts of exercise. Of the 12 subjects that participated in the study, only three subjects completed 24 hours of testing and were post-tested. All three subjects were drinking the NBC Nutrient solution when they completed 24 hours of testing. One of these subjects (#6) was ill during the control solution trial but this illness did not interfere with his results on the NBC Nutrient solution trial so his data were included.

RESULTS AND DISCUSSION

Reliability estimates were made to examine the within day test/retest reliability for the variables observed during the squats. The estimates were greater than 0.93 for all variables, except the height of peak force that had

a reliability estimate of 0.866. The test/retest reliability estimate across days were not as good as the within day estimates for the variables observed during the squats as shown in the following table:

ACROSS DAYS TEST RETEST RELIABILITY ESTIMATES

Variable	PKFORCE	HTPK	AVEFORCE	AVEPOWER	TTLWORK
Rel. esti.	.7332	.1042	.7109	.6798	.4931

Learning curves were not observed for any of the variables during the training period. Additionally, no significant differences were found when comparing the daily means for any of the variables during the training period and the two pre-test sessions. These results showed that the subjects did not undergo a significant learning process and achieved a stable baseline in these strength measures prior to the test sessions. A summary table of these results are presented below.

PRE-TEST SQUAT LIFT RESULTS (n=12)

Variable	Mean±SD
PKFORCE(Lbs)	270.0 ± 53.45
HTPK(in)	21.1 ± 6.21
AVEFORCE(Lbs)	192.5 ± 37.32
AVEPOWER(W)	789.1 ± 158.59
TTLWORK(Ft.Lbs.)	503.4 ± 119.44

There were only three subjects (#2, #6, #12) that completed either of the 24-hour heat stress trials. These subjects were all drinking the NBC Nutrient solution and the trial completed was the first of the two trials. The results of ANOVAs performed on the data from the squat lifts demonstrated that only AVEFORCE and AVEPOWER showed significant differences between the pre- and post-test measurements. These data are summarized below.

SURVIVORS SQUAT LIFT RESULTS (n=3)

Variable	Pre-test Mean±SD	Post-test Mean±SD	p
PFORCE(Lbs)	257.7±11.02	217.3±35.50	NS
HTPK(in)	22.0±4.58	20.0±6.25	NS
AVEFORCE(Lbs)	181.3±8.14	145.3±17.79	p<0.05
AVEPOWER(W)	730.3±43.98	590.3±56.62	p<0.05
TTLWORK(Ft. lbs)	409.7±24.34	371.3±97.52	NS

Although the results showed a decline in all of the strength performance variables tested, only average force production and average power production, showed statistically significant decreases ($p<0.05$) pre- to post-scenario. A recent study by Noble, Kraemer, and Fleck (1) exhibits similar results. These authors found no significant decrement in isokinetic peak leg extension torque in subjects completing 20 and 42km runs. These authors did find a significant depression ($p<0.05$) in the magnitude of the torque vs knee angle curve post

run. This resulted in a decreased total work leading to a decrease in average force and average power. The results of both studies seem to indicate that the fatigue from long term sustained exercise appears to be less related to peak force capabilities than to rate dependent strength measures. Because these tests are isokinetic measures, time and distance are proportional once the subject engages the dynamometer. This means that the variable of AVEFORCE is a rate dependent variable as is AVEPOWER.

Strength tests are very sensitive to the motivational state of the subject performing the tests. It was evident from conversations with the subjects that completed the 24-hour heat stress trials that they would "give their best effort" in the test. It was also clear that these strength tests were of a low priority, relative to sleep, food, and physical comfort. Whatever factors contribute to these low motivational states their effects are very real and serve to complicate the measurement of strength in almost all but the most ideal situations.

Another factor that interfered with the tests was the lack of adequate time for each subject to fully recover from the musculo-skeletal trauma of the first 24-hour heat stress trial before being subjected to the second trial. This short recovery time may have been needed from a logistical standpoint but it undoubtedly contributed to the inability of any subject to complete the second 24 hour test. Add to these factors sleep deprivation and it becomes almost impossible to partial out what contributes to changes in strength measures during a prolonged exercise scenario.

CONCLUSIONS

While there was a general decline in strength performance after the test, there were too many confounding factors and not a large enough number of subjects to realistically ascribe any changes in strength performance to the consumption of the NBC nutrient solution. The fact that none of the subjects drinking the control solution completed the test makes strength performance comparisons of the NBC Nutrient solution and the control solution impossible.

REFERENCE

1. Noble BJ, Kraemer WJ, Fleck SJ. Muscle strength and endurance following long distance running (abstract). American College of Sports Medicine National Meeting 1987, Las Vegas, NV.

APPENDIX 7

APPENDIX 7. SIGNIFICANT MAIN EFFECTS AND INTERACTIONS FOR TOTAL SYMPTOM SCORE AND INDIVIDUAL ESQ ITEMS

	SOLUTION ORDER	SOLUTION	ADMINISTRATION	INTERACTIONS
TOTAL SCORE	NS	8.78 0.05	15.89 0.0001	-
EYE IRRITATION	5.14 0.05	6.42 0.05	NS	SO
SHAKING HANDS	NS	13.23 0.01	4.03 0.05	-
POOR COORDINATION	NS	13.09 0.01	5.60 0.01	SA
WARMTH	NS	8.77 0.05	NS	-
STOMACH ACHE	NS	7.44 0.05	5.87 0.01	SA
IRRITABILITY	NS	7.40 0.05	NS	-
HUNGER	NS	5.61 0.05	NS	-
FEVERISHNESS	NS	5.61 0.05	NS	-
ANGER	NS	7.22 0.05	NS	SO, SAO
FEELING ACTIVE	NS	NS	31.29 0.0000	SAO
SLEEPINESS	NS	NS	38.57 0.0000	AO
LEG ACHE	NS	NS	34.40 0.0000	-
WEAKNESS	NS	NS	23.97 0.0000	-
TIREDNESS	NS	NS	21.29 0.0000	-
ALERTNESS	NS	NS	16.90 0.0001	-
MUSCLE STIFFNESS	NS	NS	15.47 0.0001	-
BACKAHCHE	NS	NS	8.89 0.01	-
HEADACHE	NS	NS	8.42 0.01	-
MALAISE	NS	NS	8.36 0.01	-
LIGHTHEADEDNESS	NS	NS	8.20 0.01	-
MUSCLE CRAMPS	NS	NS	7.68 0.01	-
STOMACH CRAMPS	NS	NS	7.64 0.01	-
DIZZINESS	NS	NS	7.23 0.01	-
SINUS PRESSURE	NS	NS	5.72 0.01	-
NAUSEA	NS	NS	5.06 0.05	-
ARM ACHE	NS	NS	4.96 0.05	-
SWEATING	NS	NS	4.48 0.05	-
FAINTNESS	NS	NS	4.31 0.05	-
POOR CONCENTRATION	NS	NS	4.13 0.05	SA
INCREASED URINATION	NS	NS	3.69 0.05	-

APPENDIX 7 continued.

	SOLUTION ORDER	SOLUTION	ADMINISTRATION	INTERACTIONS
DIM VISION	NS	NS	NS	SA
RAPID HEART RATE	NS	NS	NS	SO
STUFFY NOSE	NS	NS	NS	SO
BOREDOM	NS	NS	NS	SO, SAO

APPENDIX 8

APPENDIX 8. SIGNIFICANT MAIN EFFECTS AND INTERACTIONS FOR TOTAL MOOD DISTURBANCE SCORE AND INDIVIDUAL POMS ITEMS

	SOLUTION ORDER	SOLUTION	ADMINISTRATION	INTERACTIONS
TOTAL MOOD DISTURBANCE SCORE	NS	5.20 0.05	18.60 0.0000	-
EXHAUSTED	10.72 0.01	NS	13.07 0.001	-
BUSHED	7.67 0.05	NS	22.81 0.0000	AO
WORNOUT	5.32 0.05	NS	17.84 0.0001	SO, SAO
UNHAPPY	NS	12.62 0.01	4.15 0.05	SO, SA
GROUCHY	NS	8.12 0.05	NS	-
ANGRY	NS	7.22 0.05	NS	SO, SAO
FATIGUED	NS	6.21 0.05	24.69 0.0000	SA
CONFUSED	NS	6.14 0.05	4.35 0.05	-
RESENTFUL	NS	6.10 0.05	NS	-
READY TO FIGHT	NS	5.56 0.05	5.25 0.05	SO, SA
LIVELY	NS	NS	37.12 0.0000	SO
ACTIVE	NS	NS	31.29 0.0000	SAO
ALERT	NS	NS	21.82 0.0000	SA, SAO
PEP	NS	NS	21.24 0.0000	-
ENERG	NS	NS	20.90 0.0000	SAO
GOODNATURED	NS	NS	11.08 0.001	-
FRIENDLY	NS	NS	8.89 0.01	-
CHEERFUL	NS	NS	8.89 0.01	-
RELAXED	NS	NS	8.58 0.01	-
CONSIDERATE	NS	NS	8.06 0.05	-
VIGOROUS	NS	NS	7.30 0.01	-
DISCOURAGED	NS	NS	6.06 0.01	-
UNABLE TO CONCENTRATE	NS	NS	5.25 0.05	SA
HELPFUL	NS	NS	5.03 0.05	-
RESTLESS	NS	NS	4.29 0.05	SA, SAO
EFFICIENT	NS	NS	4.25 0.05	-
CLEARHEADED	NS	NS	3.77 0.05	-
ANXIOUS	NS	NS	NS	SAO
BADTEMPERED	NS	NS	NS	SA

APPENDIX 9

SUBJECT______________ TIME_____________ CONDITION______________

Please answer every question. Circle the number on each scale that best reflects how you feel right now and/or your opinion of the fluid at this particular time.

1. How THIRSTY do you feel right now?

0	1	2	3	4	5	6	7	8	9
not thirsty									extremely thirsty

2. How HUNGRY do you feel right now?

0	1	2	3	4	5	6	7	8	9
not hungry									extremely hungry

3. How ALERT do you feel right now?

0	1	2	3	4	5	6	7	8	9
not alert									extremely alert

4. How physically STRONG do you feel right now?

0	1	2	3	4	5	6	7	8	9
not strong									extremely strong

5. How much do you LIKE or DISLIKE this fluid?

1	2	3	4	5	6	7	8	9
dislike extremely				neither like nor dislike				like extremely

6. How SWEET is this fluid?

0	1	2	3	4	5	6	7	8	9
not sweet									extremely sweet

7. How SALTY is this fluid?

0	1	2	3	4	5	6	7	8	9
not salty									extremely salty

8. How intense is the lemon-lime FLAVOR of this fluid?

0	1	2	3	4	5	6	7	8	9
no flavor									extremely strong flavor

9. How SOUR is this fluid?

0	1	2	3	4	5	6	7	8	9
not sour									extremely sour

10. How COOL or WARM is this fluid?

1	2	3	4	5	6	7	8	9
extremely cool				neither warm nor cool				extremely warm

APPENDIX 10

Post Test Questionnaire

Please answer every question. On questions 1-6, circle the number on
scale that best reflects how you feel. On questions 7 and 8, fill in
responses on the lines provided.

1. Now that the test is over, how much did you like the fluid that wa
provided to you?

   1. Disliked Extremely
   2. Disliked Very Much
   3. Disliked Moderately
   4. Disliked Slightly
   5. Neither Liked nor Disliked
   6. Liked Slightly
   7. Liked Moderately
   8. Liked Very Much
   9. Liked Extremely

2. How much did you like this fluid compared to plain water?

   1. Disliked it much more
   2. Disliked it somewhat more
   3. Liked/Disliked it the same
   4. Liked it somewhat more
   5. Liked it much more

3. Did the fluid seem to give you more energy than plain water?

   1. Much more energy
   2. Somewhat more energy
   3. No difference
   4. Somewhat less energy
   5. Much less energy

4. If you had only this fluid to drink in the field would you mind?

   1. Not at all
   2. I would mind somewhat
   3. I would mind very much

5. Of the following choices, which would you prefer to carry with yo

   1. Two canteens of this fluid
   2. Two canteens of water
   3. One canteen of this fluid and one canteen of water

6. Did this fluid give you a psychological "lift"?

1. Not at all
2. Somewhat of a "lift"
3. Very great "lift"

7. What did you like best about this fluid and why? ______________________

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8. What did you like least about this fluid and why? ______________________

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